LEDREW ENVIRONMENTAL MANAGEMENT LIMITED

ENVIRONMENTAL PREVIEW

# GREENSPOND CAUSEWAY

## PHYSICAL OCEANOGRAPHY AND FISHERIES

A REPORT TO

**DEPARTMENT OF TRANSPORTATION**

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

JULY, 1982

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By:

LEDREW ENVIRONMENTAL MANAGEMENT LTD.

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## INTRODUCTION

The Department of Transportation contracted this environmental study to evaluate the impacts of a proposed causeway on water circulation and fishing activities in the vicinity of Greenspond Island. These issues were identified as concerns that needed to be addressed before project release could be considered.

The objectives of the study were defined as:
1)describe the present water circulation in Greenspond Tickle;
2)predict changes in water circulation which will occur after installation of the proposed causeway and bridge; and
3)predict impacts on fish and fisheries as a result of construction and operation of the causeway.

The study was conducted by combined efforts of LeDrew Environmental Management Ltd., Oceans Ltd., and McElhanney Surveying & Engineering Ltd.

LeDrew Environmental Management Ltd. was responsible for the overall project management, the section dealing with the fisheries environment and its predicted impacts, and preparation of the final report. Oceans Ltd. carried out the physical oceanography portion of the study dealing with the water circulation and projected changes. McElhanney Surveying & Engineering Ltd. carried out the field program involving the mooring of a current meter and current profiling across Greenspond Tickle.

This report is intended to form part of an Environmental Preview Report required by the Department of Environment. Such a report is intended to identify important environmental issues associated with the project, and thereby enable a decision to be made on the need for a full scale Environmental Impact Assessment.

## METHODS

An Aanderaa (RCM-4) current meter was deployed at mid-depth in Greenspond Tickle for the period May 10 to June 7, 1982. During deployment and recovery, a series of current profiles were obtained from three stations across the Tickle using a Braystoke Profiling Current Meter. Profiles were obtained from three stations for the falling and rising tide on June 7. One profile was obtained on the rising tide on May 10. As well, on May 10 two bottom grabs were attempted to sample the substrate.

The data tape obtained from the current mooring was translated by Aanderaa Instruments Ltd., Vancouver B.C. The data results were supplied on computer print-out and 9 track magnetic tape.

Additional information on the physical environment was obtained from various sources to aid in the interpretation of the water current data. Wind data for the study period was obtained from the meterological station at Cape Bonavista. Statistics for wind speed and direction over the last ten years were compiled by the Climatology Branch of Atmospheric Environment Service (AES), Ottawa.

Tidal heights for the Valleyfield area were predicted by the Marine Environmental Data Service (MEDS), Ottawa.

Fisheries statistics were provided by Economic Services Branch, federal Fisheries and Oceans, St. John's. Statistical Section 10 includes the study area and is the most precise information available. Numbers of fisherman as well as fishing boats (by size category) were available by community. No information on fishing gear was available.

Personal interviews were conducted with several residents of the study area to obtain site specific information on fishing and fish plant operations in the Greenspond Tickle area. Persons contacted are noted in the report.

Contact was made with federal Fisheries Research Scientists and Biologists to update the literature and obtain information on local research efforts. Those contacted included Mr. John Moores (herring), Dr. George Winters (capelin), Dr. Gerry Ennis (lobster), Dr. Henry Lear (cod),and Mr. Rex Porter (salmon). In provincial Fisheries contact was made with Mr. David Aggett, Mr. Ken Mercer (lumpfish) and Mr. Harold Murphy (fishing operations).

A literature search was conducted using the computerized data bases available at Memorial University of Newfoundland Library. The computer search included biological as well as oceanographic key words along with engineering terms such as causeway and breakwater.

## PROJECT DESCRIPTION

Greenspond Island is located on the northern side of Bonavista Bay (Figure 1). It is an isolated community presently serviced by a seasonal ferry from Valleyfield. Road access to Greenspond Island will be achieved by construction of a 0.8 km long rock causeway from Shamblers Cove to the island (Figure 2). The causeway will include a concrete bridge to allow for boat movement through Pond Tickle.

An existing road access to Shamblers Cove will be upgraded and connected to the causeway. On Greenspond Island, the causeway will be interconnected with an existing road. A total of 1.3 km of approach road will be constructed or upgraded.

The work will proceed in two stages, with the initial contract dealing with construction of the causeway and road connections. It is expected that this will be completed within 17 months. At the second stage, a contract will be let for construction of the bridge. This facility will span 30 m with a clearance of 3 m at low water level. This will enable passage of small open boats (but not longliners).

Construction will entail a limited amount of clearing and grubbing (0.2 ha clearing; 1.6 ha grubbing) on the right of way.

The major activity will involve quarrying and placement of fill material. The volumes of material are estimated and shown below

| Material | Volume ($m^3$) |
|---|---|
| Excavation - Solid Rock | 32,000 |
| Quarried rock | 450,000 |
| Armour stone | |
| 0.75 $m^3$ minimum volume | 20,700 |
| 1.15 $m^3$ minimum volume | 13,400 |
| 1.50 $m^3$ minimum volume | 9,200 |
| Stockpile 1.50 $m^3$ minimum volume | 2,300 |
| Other material | 4,000 |
| Borrow, topping | |
| (sub grade class C) | 4,000 |
| Guide rail | 1,700 m |
| 60 cm diameter CIP | 48 m |

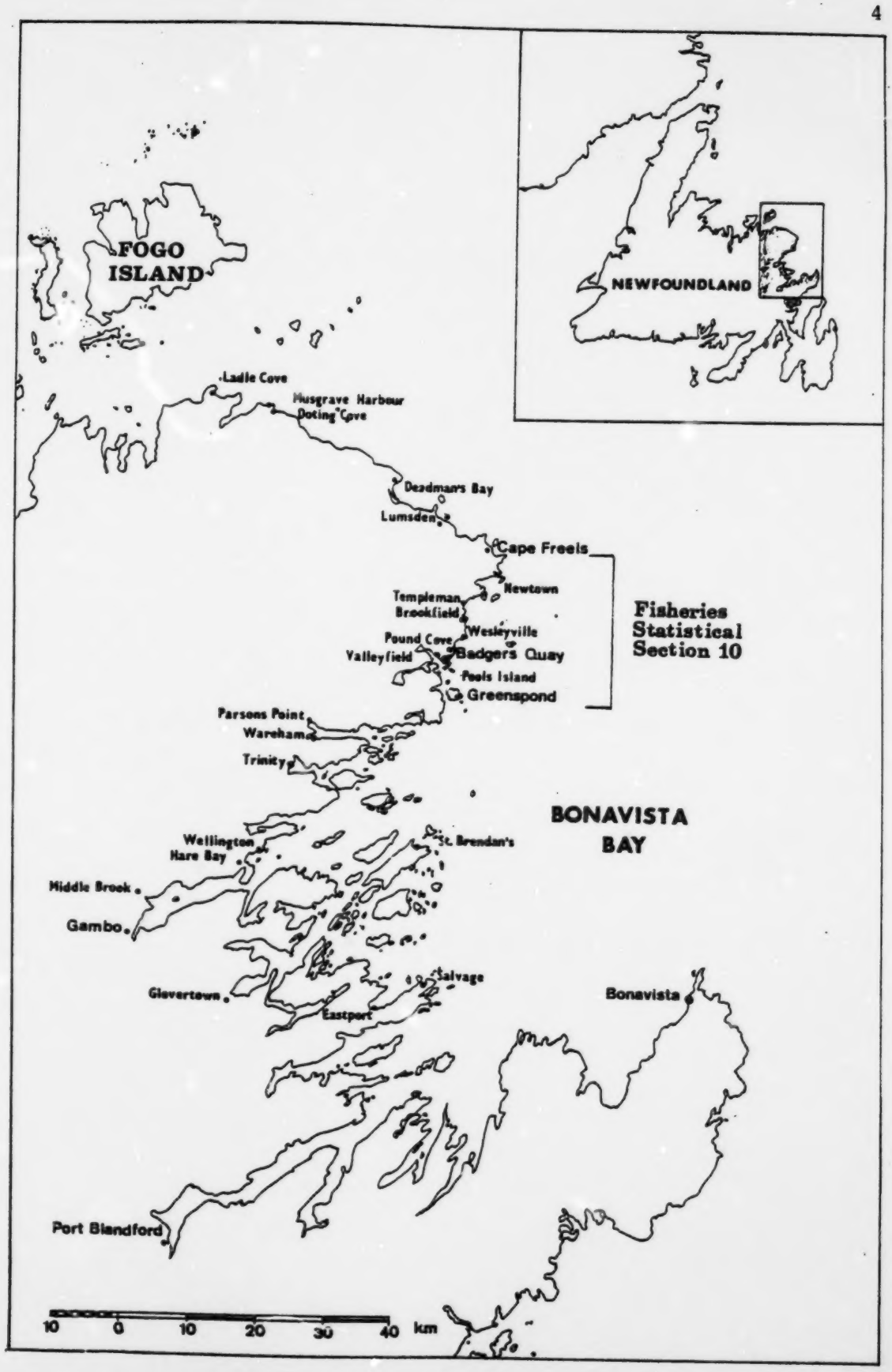


Figure 1 Location of study site

It is expected that quarry material will be found within the work site or from existing sites along the Shamblers Cove road.

Construction will involve three phases. In phase I quarried rock fill will be placed up to an elevation of 1.0 m above mean sea level for the designated full width. In phase II, the sides of fill will be excavated to accomodate the armour stone which will then be placed within designated limits up to elevation 1.0 m. In the last phase, fill will be placed in lifts leaving room on each side for armour stone . The remaining armour stone will be placed as required.

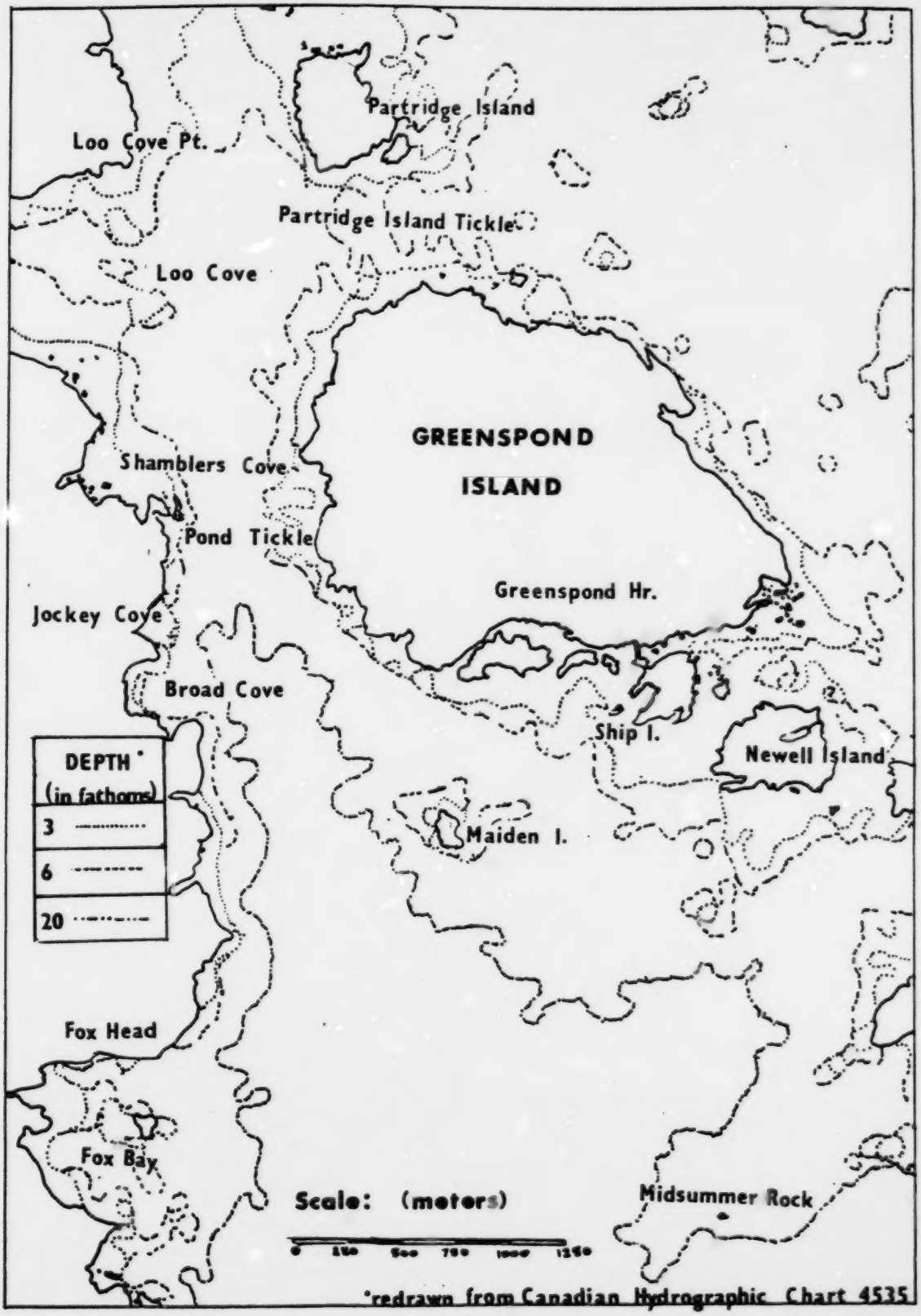


Figure 2 Study area

# THE EXISTING ENVIRONMENT

## PHYSICAL OCEANOGRAPHY

### Labrador Current

Cold water in Bonavista Bay can be attributed to the inshore branch of the Labrador current. This water originates as a mixture of cold, low salinity water from Hudson Strait and from the Baffin current. The inshore branch of the Labrador current flows along the Labrador coast following the contours of the Labrador Marginal Trough until it reaches the vicinity of Belle Isle. At this point, part of the inshore branch flows into the Gulf of St. Lawrence through the Strait of Belle Isle and the other part flows along the northeast coast of Newfoundland to the Grand Banks.

The Labrador current is extremely dynamic with variabilities on several time scales. The most noticeable time scales occur in the range from a tidal cycle to several days . At any given time the current may be in any direction, but in general the dominant flow follows the contours along the northeast Newfoundland coast. The general current pattern in the vicinity of Bonavista Bay is presented in Figure 3. This figure illustrates that the dominant current flowing into Bonavista Bay is located approximately 15 km southeast of Greenspond Island. However, there is a deep channel which extends in an east-west direction in the region south of Greenspond Island. Some Labrador current water can flow further inshore through this channel, particularly during occurrences of strong onshore winds.

An example of the temperature and salinity structure offshore Cape Bonavista is given in Figure 4, as presented by Templeman (1972). This figure shows the cross-sectional temperatures and salinities for August 1-2, 1971. During the summer months the subsurface temperatures can be expected to be in the range $0^{\circ}$ C to $-1.6^{\circ}$ C and salinities in the range 31.5 0/00 to 33.0 0/00. The salinities and temperatures of this water mass are variable from year to year (Templeman, 1975). Even more variability is produced by seasonal changes. In general, this water mass will be colder and have a higher salinity than the coastal water in the shallow regions near Greenspond Island.

An attempt was made to identify the boundary of the colder Labrador current through satellite photographs but the resolution was inadequate for the scale of interest.

### Pond Tickle

This stretch of water is approximately 0.62 km wide and has a maximum depth of 26 m (Figure 2). It is quite shallow towards either shore. During current meter recovery operations, an effort was made to sample the bottom material. Two grabs were made: one brought up a relatively large rock and sea urchins; the other yielded fine sand and sea urchins. The comment made by the crew of the charter vessel was to the effect that the bottom is hard gravel, rock and some sandy spots.

The shoreline is rocky on both sides of the Tickle. Each year landfast ice forms in the Tickle and freezes to a thickness that can be traversed by snowmobile.

Figure 3 General pattern of the Labrador current in vicinity of Bonavista Bay (Depths are in metres)

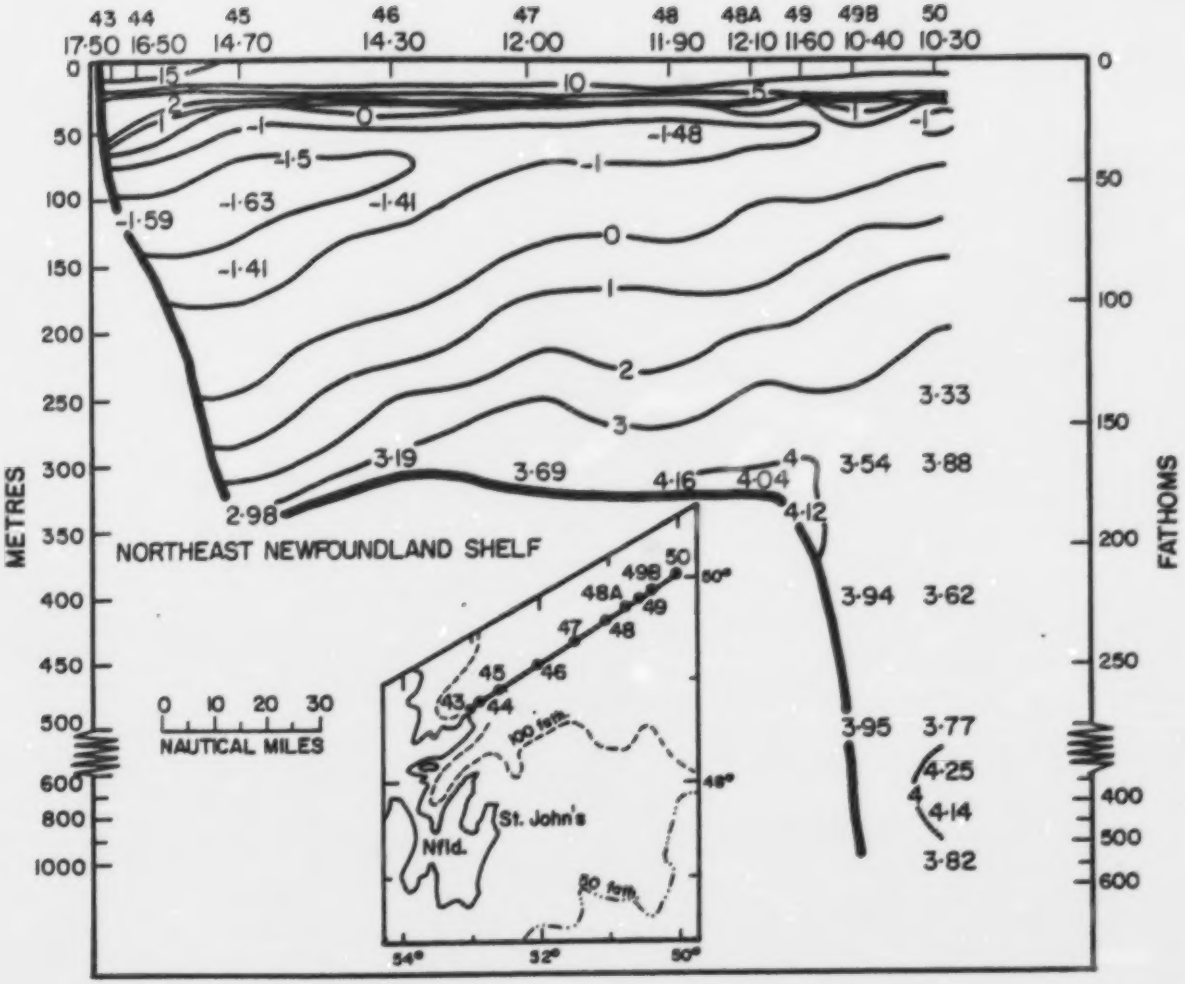


Figure 4 Temperatures and salinities offshore Cape Bonavista during August 1-2, 1971 (from Templeman 1972)

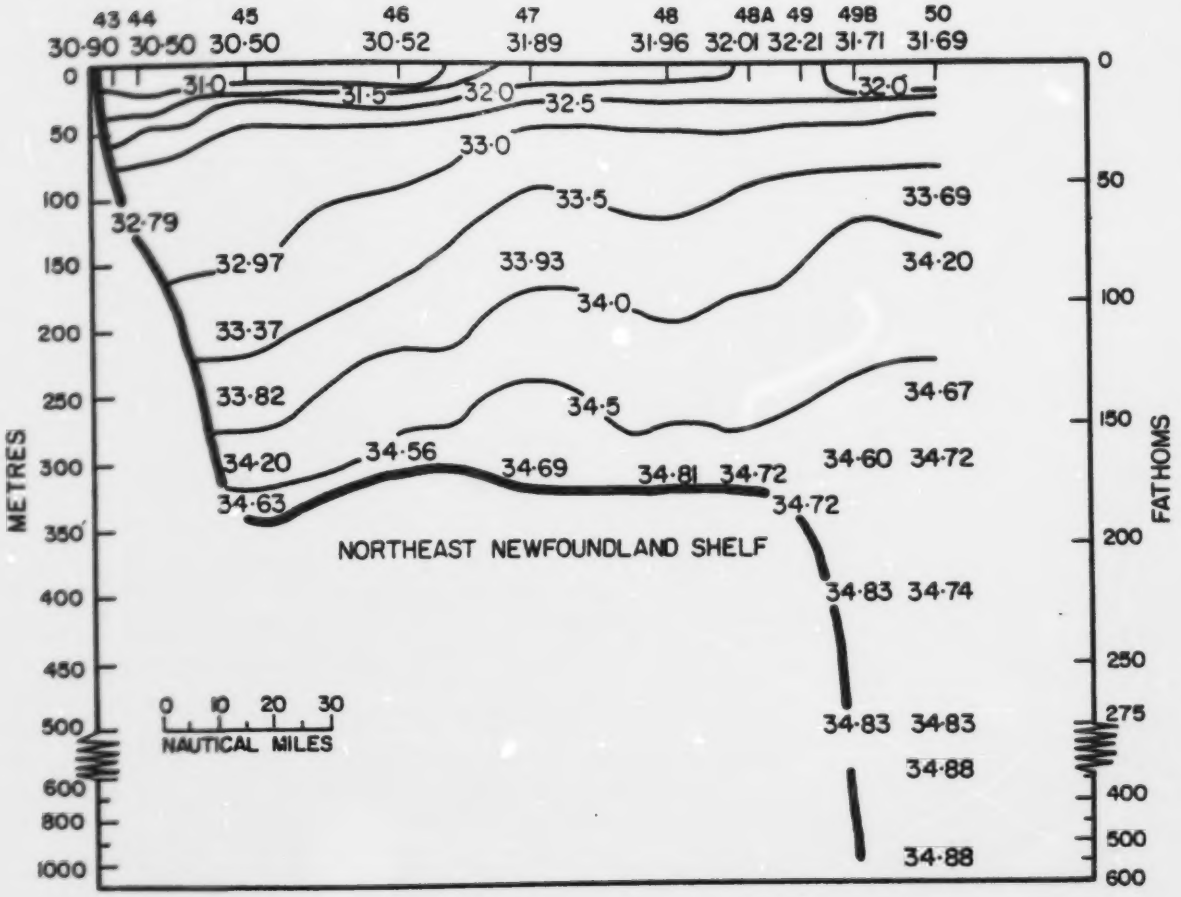


Figure 4 (continued)

Figure 5 shows the geometry of the location where the proposed causeway is to be built. The total cross-sectional area of the study site is 8660 $m^2$ at mean water level.

The flow through Greenspond Tickle is restricted due to shallow bathymetry to the north and northeast, and by Partridge Island located in the middle of the northeastern entrance. In the section between Partridge Island and the mainland the flow is restricted by water depths of less than 5 m. Between Partridge Island and Greenspond Island water depths are generally less than 8 m except for a narrow channel that has width of less than 0.1 km and a depth of 12 to 14 m. The whole area extending from Greenspond Island to Cape Freels is shallow with much of the area having depths less than 30 m. A large portion of the nearshore waters is less than 10 m depth.

The flow through Greenspond Tickle is further restricted by a chain of islands which extend to the southeast: Ship Island, Newell Island, Puffin Island, Pigeon Island and Copper Island. To the south of Greenspond Tickle, deeper water occurs with depths between 20 and 90 m extending for approximately 4 km. At this location the depths increase from 90 to 300 m and then become shallower again at a distance of approximately 6 km. The channel runs in an east-west direction from nearshore to the deeper waters of Bonavista Bay. This is the only area in the vicinity of Greenspond Island where the colder water of the Labrador current can reach inshore.

Dominant Currents in Greenspond Tickle

An Aanderaa current meter was moored at mid-depth in Greenspond Tickle from 1335 (GMT) May 10 to 1545 (GMT) June 7, 1982. The meter was moored at a depth of 13 m near mid-channel where the water depth was 24 m. This location was chosen to be representative of the flow in the Tickle. The meter was placed at a sufficient depth below surface for minimal influence from surface wave induced motions.

The dominant current in Greenspond Tickle was found to be aligned in a north-south direction along the channel. An analysis of the current meter data showed that the currents are mainly wind-driven. The wind-driven current is so pronounced that the tidal flow is almost totally obscured. The only instances where a tidal flow is clearly evident are during the period May 10 - May 12 and May 22 - May 24. Stick diagrams representing the current during these days are shown in Figures 6 and 7.

Spring tides during the sampling period occurred on May 6, May 22, and June 6. The maximum tidal ranges as predicted by the Marine Environmental Data Service were 1.02 m, 1.12 m, and 1.07 m, respectively. An interesting feature of the tidal flow is that during flood or ebb, the current in the Tickle may be flowing either north or south. This contrasts with most areas where flood tide has one direction and ebb tide flows in the opposite direction. In Greenspond Tickle there appears to be a tendency for flood tide to be directed north and ebb tide to flow south. These directions are not consistent due to the low magnitude of the tidal current (which has a value of approximately 10 cm/sec during spring tide) and the overall dominating effects

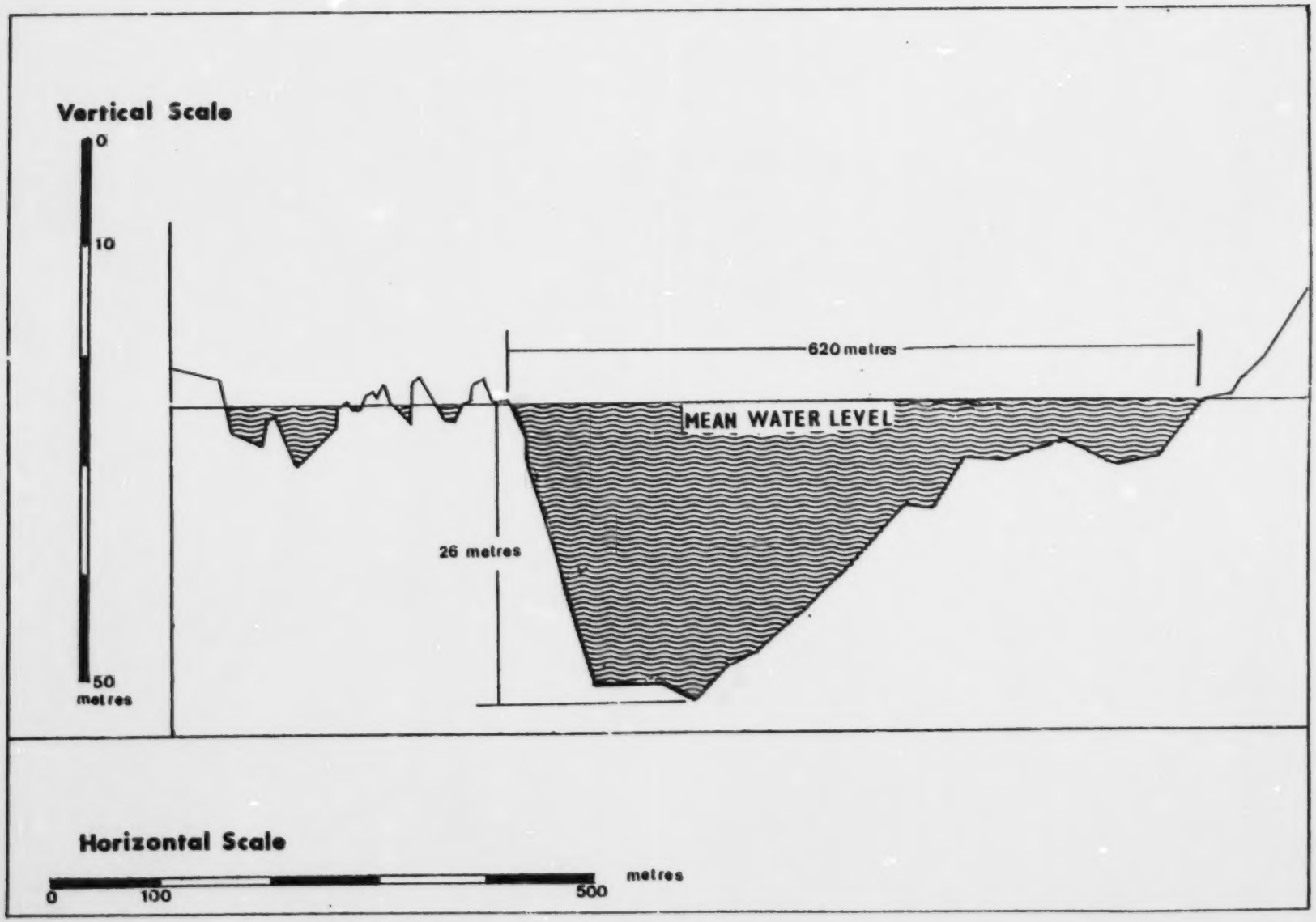


Figure 5 Cross-sectional area of study site

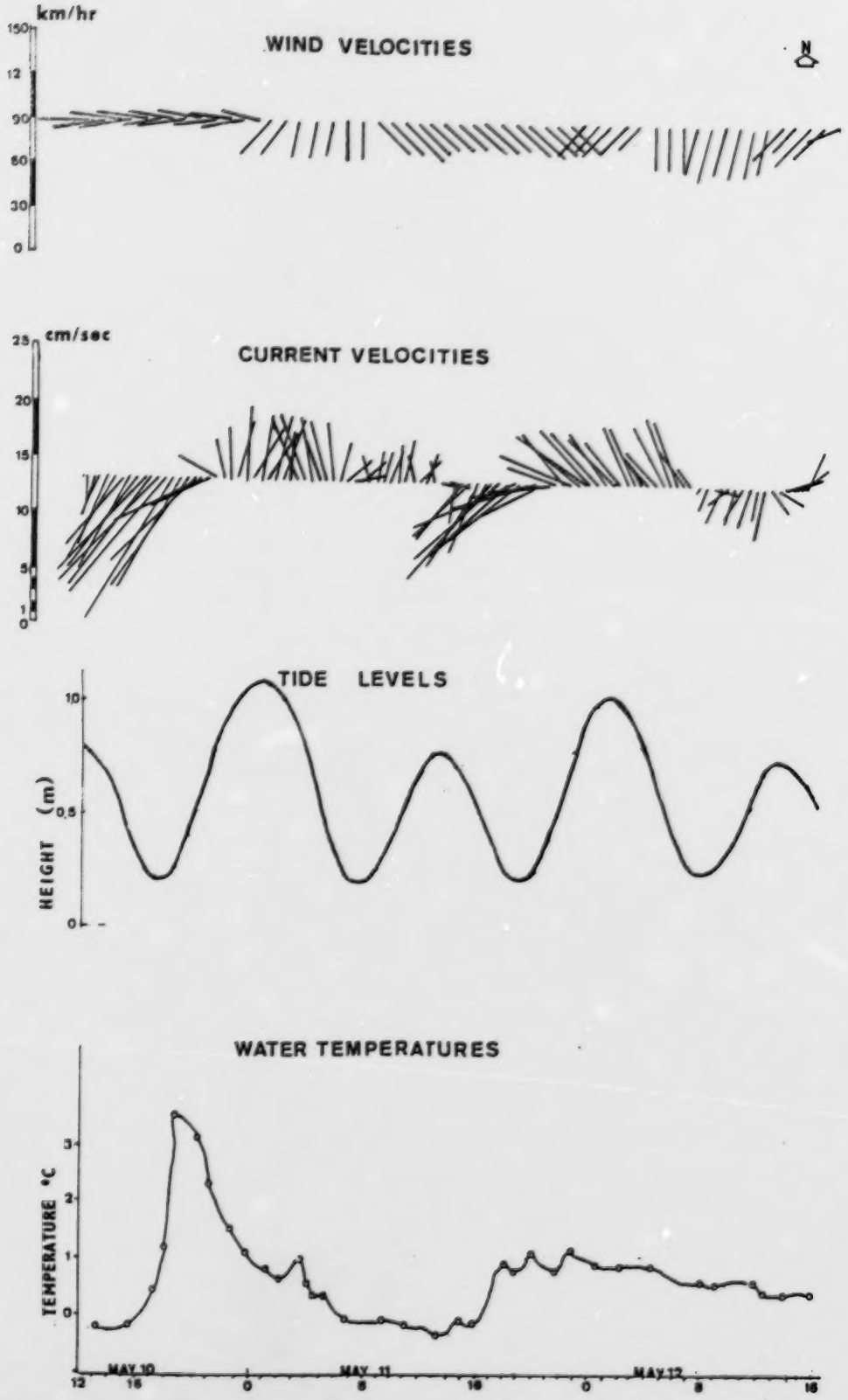


Figure 6 Winds, currents, tides, and water temperatures for May 10-12, 1982

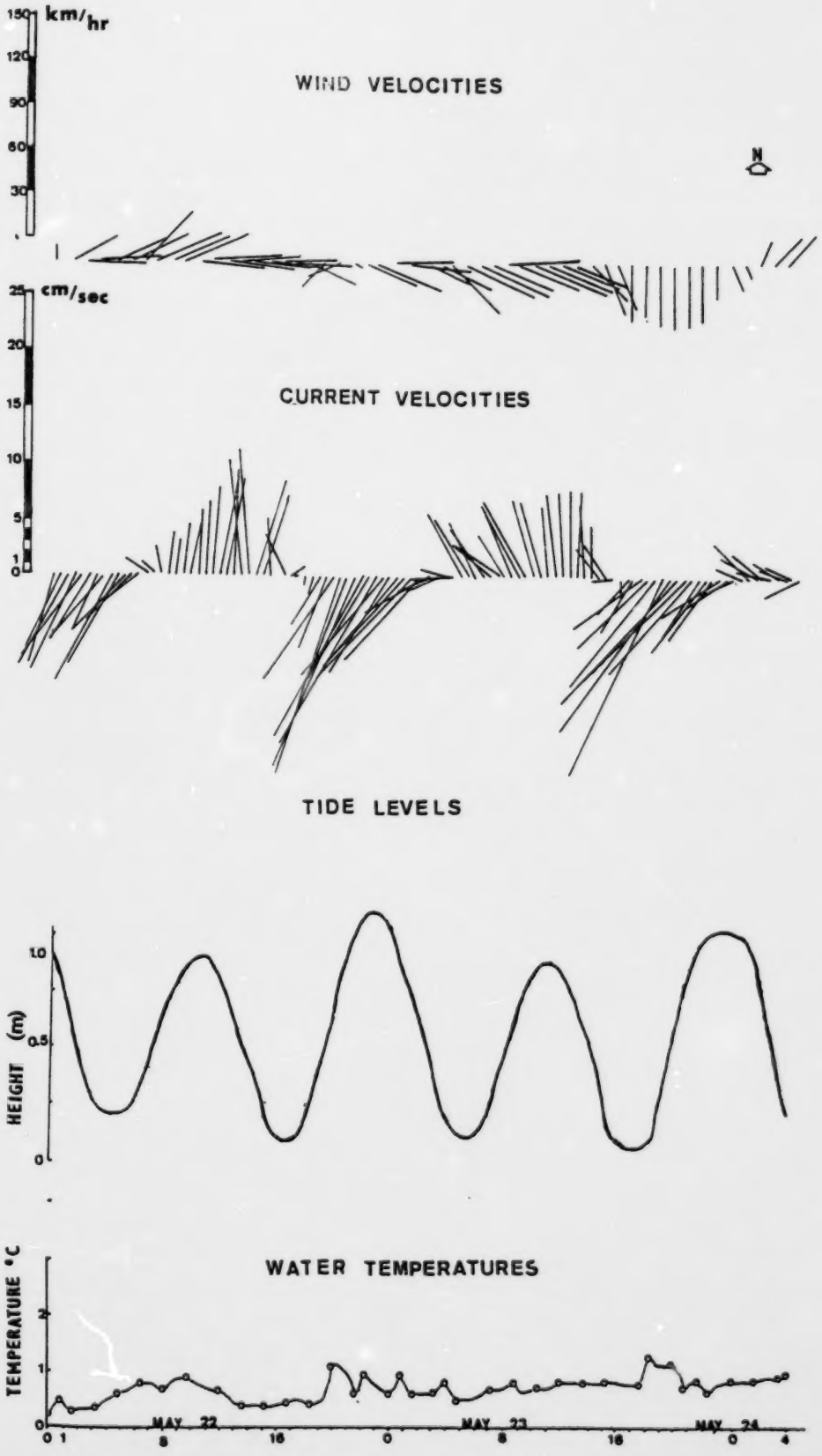


Figure 7 Winds, currents, tides, and water temperatures for May 22-24, 1982

of the winds. Since the value of 10 cm/sec. still has some wind effects superimposed, the true tidal current will be even less. When the winds are from the west, the current tends to flow north during both flood and ebb tide. The reverse situation occurs when the winds are from the east. The direction of flow is mainly dependent on the sea level slope, therefore the current directions indicate that during onshore winds the water level tends to be higher to the north of Greenspond Island than to the south. The reverse situation occurs during instances of offshore winds.

Figures 8 to 10 illustrate the extent to which the wind-driven currents are the most dominant aspect of the flow in Greenspond Tickle. The current magnitudes cannot be directly related to the wind magnitudes because the winds are from the meteorological stations on Cape Bonavista, located about 55 km from the study site. Nevertheless, the wind data is believed to be fairly representative since the station at Cape Bonavista is situated in an exposed area avoiding the problems associated with local topography. Figure 8 shows 25at on May 18 during northeast winds of 40 - 50 km/hr, the current was directed south with a speed of 25 - 30 cm/sec. Similarly, on June 3, south - southeast winds of 40 - 60 km/hr produced a northward directed current of approximately 27 cm/sec. Figure 9 shows that on May 30, winds from the north with magnitudes of 35 - 40 km/hr produced a southward flowing current of approximately 30 cm/sec. On May 31, when the wind reversed direction the current also changed direction. The speeds of both wind and current remained similar after the directions were reversed.

The most noticeable feature of the water properties in Greenspond Tickle is that the temperatures are highly variable. The water to the north and northeast of Greenspond Island is warmer and has a lower salinity than the water to the south. This latter water is influenced by the inshore branch of the Labrador current flowing into Bonavista Bay. When the wind was from the northeast, the water in Greenspond Tickle was found to become relatively warm with temperatures between 2° C and 3° C. When the wind was directed from the south or southeast this warm water mass became replaced by colder and higher salinity Labrador current water. During instances when the winds and currents changed, the water temperature was found to change by as much as 3 to 4 Celsius degrees, as shown in Figures 6 and 10. This temperature difference may be even greater during the summer months when the shallow area to the north and northeast of Greenspond Island becomes much warmer from solar heating.

Residual Flow

The current in Greenspond Tickle is aligned along the axis of the Tickle flowing in either a northerly or a southerly direction. Since the currents are mainly wind-driven, any residual flow through the Tickle will depend on the prevailing wind directon. During the sampling period, the wind blew from the direction of north to east - northeast for 23% of the time, and from the directions of southeast to southwest for 30% of the time. During this period, the current flowed south with a 42% frequency and flowed north with a 58% frequency, therefore, the amount of time the current flows north or south appears to correspond well with the wind direction. Greater differences in direction frequencies between winds and currents can be expected due to discrepancies in wind directions between Cape Bonavista and the study area, and to the currents produced by the sea level slope when the winds are from the east or west.

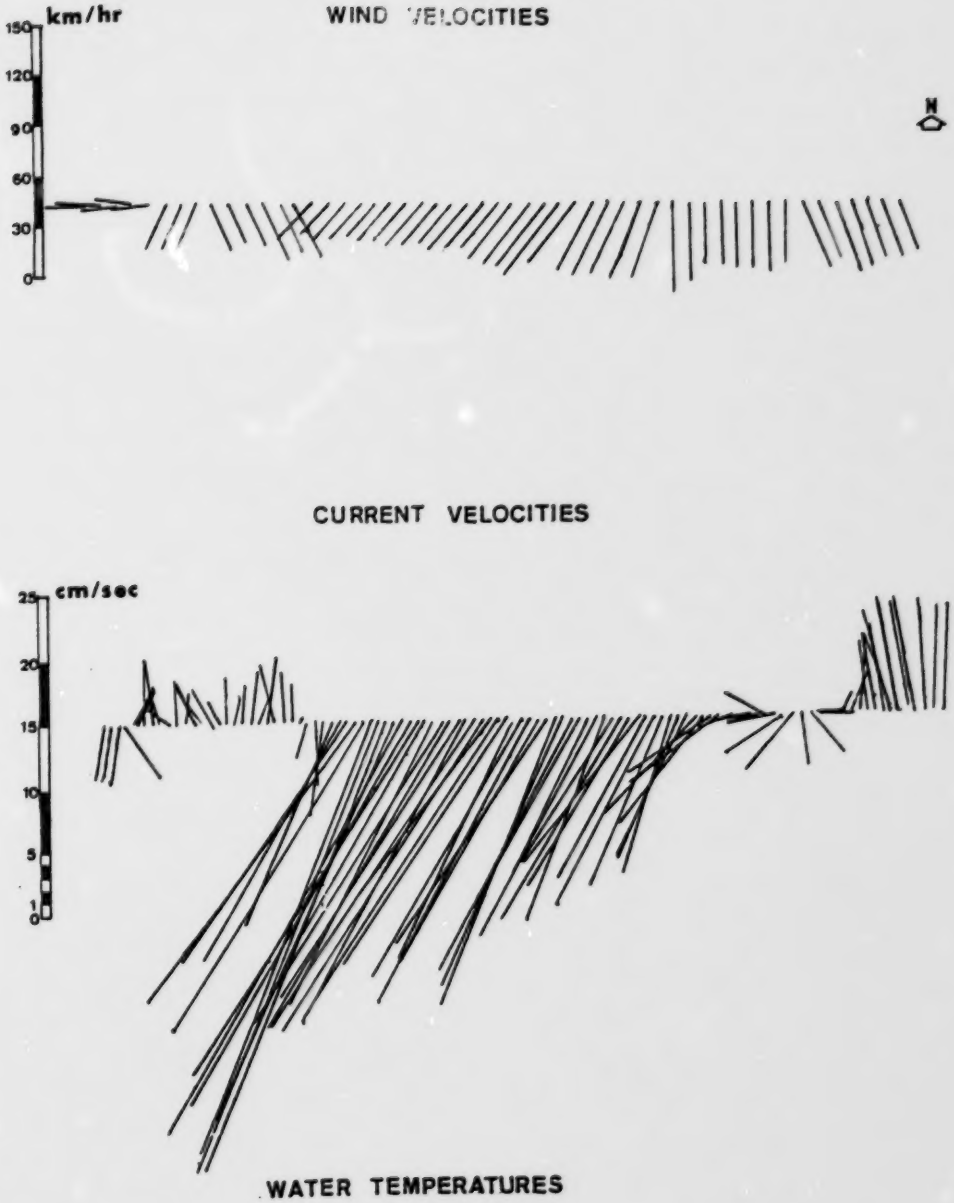


Figure 8 Winds, currents, and water temperatures for May 17-19, 1982

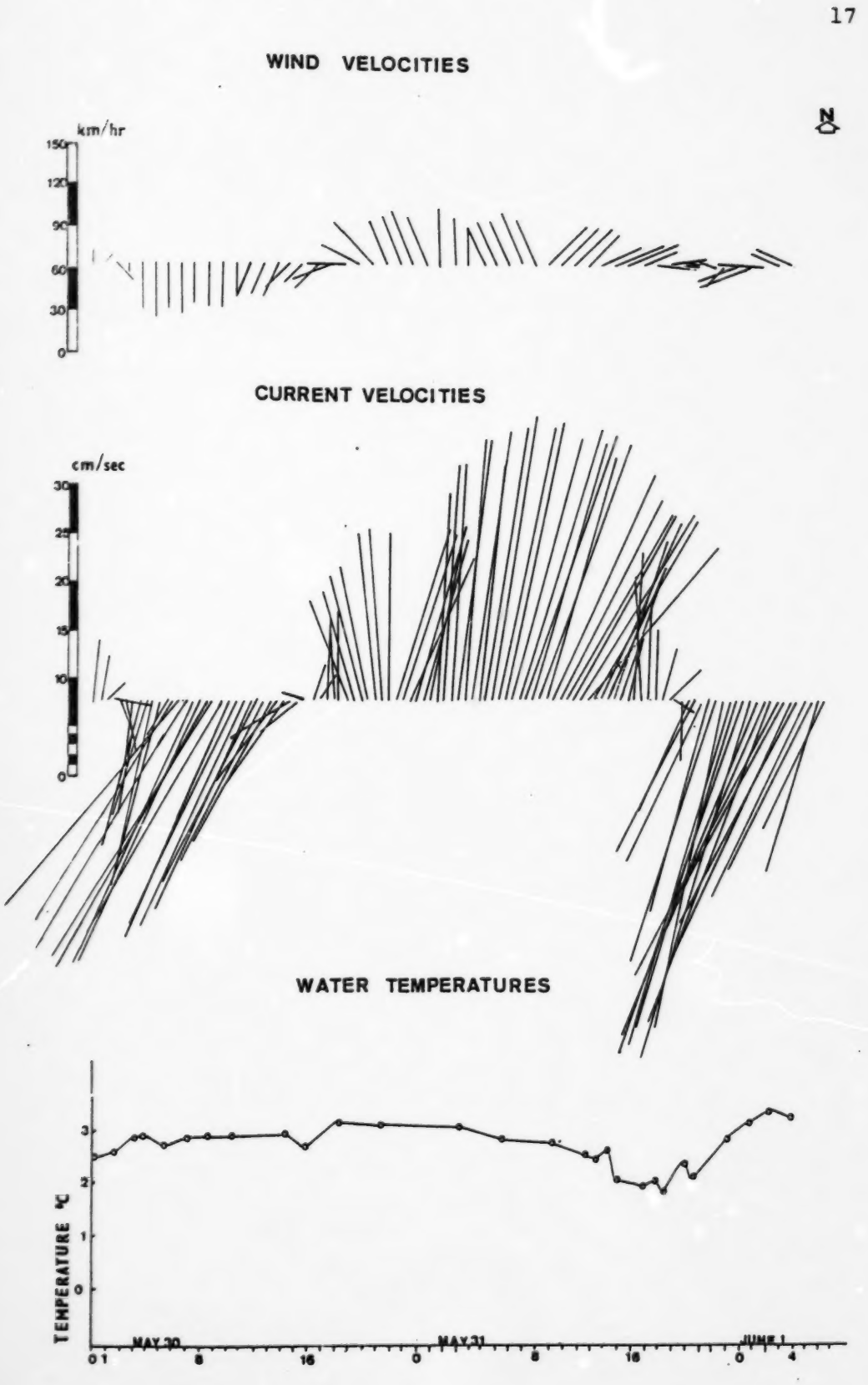


Figure 9 Winds, currents, and water temperatures for May 30-June 1, 1982

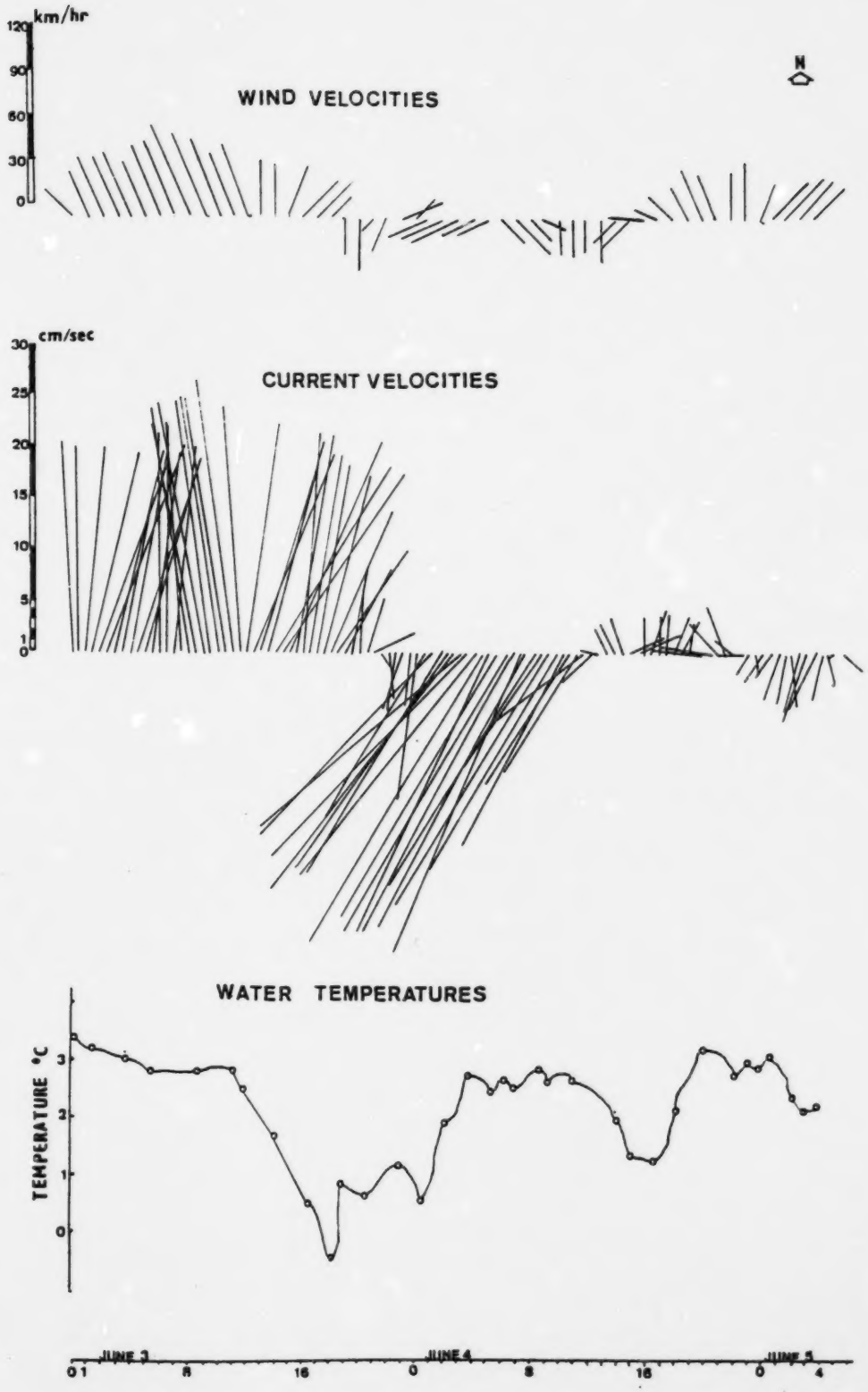


Figure 10 Winds, currents, and water temperatures for June 3-5, 1982

Wind data for Cape Bonavista for the period 1971 to 1980 are shown in Table 1 . This data shows that the prevailing winds are from the directions southwest to west with a frequency of 34% . The winds are from the southwest to southeast for 36% of the time and from the north to east - northeast for 12% of the time. This indicates that the wind-driven currents are directed northward through the tickle with a greater frequency than the southward flowing currents. Bi-variate histograms of the wind speeds and directions for each month are shown in Appendix 2. The wind directions also indicate that the colder Labrador current water influences the water properties in Greenspond Tickle throughout the year. The greatest significance still remains in the variability in water properties when the winds change direction.

Table 1 -

Bi-variate histogram of wind speeds and directions for Cape Bonavista, 1970-1981 inclusive.

| WIND DIRECTION | NO. OF OCCURRENCES | WIND SPEED CLASES (KM/HR) 1-10 | 11-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | 81-90 | 91-100 | 100 | Mean Speed | Percentage of Occurrences according to Direction |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NNE | 2,047 | 215 | 529 | 545 | 449 | 179 | 84 | 32 | 12 | 2 | | | 27.0 | 2.3 |
| NE | 2,526 | 297 | 626 | 592 | 542 | 233 | 142 | 71 | 13 | 6 | 3 | 1 | 28.0 | 2.9 |
| ENE | 2,336 | 325 | 570 | 479 | 499 | 250 | 130 | 67 | 10 | 4 | 2 | | 27.7 | 2.7 |
| E | 4,095 | 546 | 1,200 | 958 | 831 | 311 | 157 | 57 | 20 | 13 | 2 | | 25.7 | 4.7 |
| ESE | 4,571 | 433 | 1,492 | 1,282 | 869 | 255 | 145 | 64 | 21 | 4 | 4 | 2 | 25.3 | 5.2 |
| SE | 3,950 | 275 | 1,068 | 1,078 | 986 | 288 | 175 | 55 | 20 | 5 | | | 27.7 | 4.5 |
| SSE | 4,097 | 328 | 1,015 | 1,160 | 1,016 | 300 | 181 | 66 | 22 | 7 | 2 | | 27.7 | 4.7 |
| S | 6,526 | 359 | 1,693 | 2,289 | 1,635 | 364 | 145 | 31 | 6 | 2 | | 2 | 26.4 | 7.4 |
| SSW | 6,596 | 218 | 1,228 | 2,509 | 2,115 | 386 | 107 | 26 | 5 | 1 | | 1 | 28.0 | 7.5 |
| SW | 10,101 | 260 | 1,557 | 3,521 | 3,780 | 676 | 207 | 66 | 21 | 11 | 1 | 1 | 29.6 | 11.5 |
| WSW | 9,343 | 461 | 1,478 | 2,259 | 2,925 | 1,083 | 619 | 292 | 151 | 50 | 13 | 12 | 32.9 | 10.7 |
| W | 10,034 | 481 | 1,169 | 1,835 | 2,905 | 1,785 | 1,073 | 506 | 204 | 67 | 8 | 1 | 36.5 | 11.4 |
| WNW | 5,985 | 276 | 680 | 1,166 | 2,113 | 1,000 | 478 | 176 | 57 | 25 | 5 | 9 | 34.8 | 6.8 |
| NW | 5,320 | 246 | 675 | 1,056 | 1,711 | 859 | 511 | 188 | 46 | 21 | 6 | 1 | 34.8 | 6.1 |
| NNW | 4,918 | 250 | 730 | 1,105 | 1,398 | 685 | 457 | 196 | 77 | 18 | 1 | 1 | 34.1 | 5.6 |
| N | 3,839 | 286 | 925 | 1,109 | 906 | 349 | 150 | 74 | 28 | 10 | 2 | | 28.3 | 4.4 |
| CALM | 1,388 | | | | | | | | | | | | | 1.6 |
| TOTAL | 87,672 | 5,256 | 16,635 | 22,943 | 24,680 | 9,003 | 4,761 | 1,967 | 713 | 246 | 49 | 31 | 30.05 | 100.0% |

## FISH AND FISHERIES

There are no site specific studies available on the marine biota in the area of Greenspond Tickle so this discussion is, of necessity fairly general. From the information gathered on fishing activity, there is a fair knowledge of the commercial species inhabiting the area, and their utilization of that habitat. The following discussion provides life history sketches of these species. Emphasis has been given to those life history stages carried out in the study area and potentially affected by the project.

### Cod (Gadus morhua)

The discussion is based on Templeman (1966) and Lear (pers. com.).

Cod spawn in late winter to early spring in offshore waters. The eggs are buoyant and float near the surface during 5 - 7 weeks of incubation. The larvae are planktonic for several months and settle to the bottom gradually when 5 - 7 cm in length. Fish mature and first spawn at age 3 - 5 years.Cod become vulnerable to fishing at about age 4 years.

There is a general onshore movement following spawning when younger, smaller fish move inshore to feed on capelin. The extent of inshore movement is closely related to water temperature and this can have a dramatic effect on vulnerability to fixed fishing gear (cod traps). The cod move to shore in the warmer surface layer of water. Older, larger cod remain offshore in deep water below the intermediate colder water.

The extent of inshore movement is related to the depth of the surface warm water layer. If it is thick, cod may remain offshore in relatively deep water and hence are unavailable to traps set in shallow water. Later in the season the surface layer usually becomes too warm for cod and they more to deeper cooler water. Wind mixing, extent of sunshine and lateness of the ice season can all affect water temperature, and hence cod movemnet to the inshore waters.

### Lobster (Homarus americanus)

This discussion is based largely on Rutherford, Wilder and Frick (1967) and Ennis (pers. com.) plus other references as cited.

The American Lobster occurs throughout the coastal waters of the island of Newfoundland. They are most abundant on rocky bottom but are also found on sand and, less frequently on mud. Deep water populations do occur but generally they are coastal animals found to depths of 50m.

Lobster grow by moulting, the process of shedding its hard shell. While the new soft shell is hardening the lobster absorbs sea water to swell to a new size.Moults occur 5 - 7 times in the first year and less frequently thereafter. Commercial sized lobster moult once a year but may miss a moult in a cold year or moult twice in a warm year.

Lobster in Newfoundland mature at a size of about 225 mm. Mating occurs after the female has moulted. Eggs are laid June - September and adhere to the females walking legs. The eggs incubate on the "berried" females for about a year.

The larvae hatch over about a two week period, and upon hatching enter the water column as free swimming larvae. Following the fourth moult the larvae settle on bottom.

The difficulty of sampling planktonic larvae has made it impossible to relate larvae abundance (in the water column) to population recruitment in a local area (Sastry and Pechenik, 1977).

Once lobster settle out of the water column, their movements are fairly local. Tagging studies indicate that distance travelled varies with size. Smallest lobsters move the shortest distance (Stasko and Graham, 1976). Lobster wander a fair amount over a 1 - 2 km area during a summer season. Lobster also exhibit a seasonal shift in depth and this is related to temperature. In the fall when the thermocline is broken and temperatures are reasonably uniform though the water column, lobster move to depths in the order of 40 m. In spring and summer lobster move upslope (inshore) to stay above the thermocline. Onshore winds can destroy the temperature gradient and result in downslope (offshore) movement.

The lobsters activity pattern is markedly affected by temperature, and directly affects catchability. For example sudden changes in bottom water temperature resulting from upwelling of cold deep water, can dramatically reduce movement until the lobster acclimates.

Lobster generally prefer rocky bottom (Cobb,1977) or areas where boulders and stone overlay sand. Lobsters tend to inhabit areas which offer appropriate shelter or can be modified (by borrowing) to provide a shelter. Experiments have been reported by several researchers (for example see Scarratt, 1968) where artificial habitat has been provided in an effort to increase lobster abundance. In the short term, numbers in the local area have increased, but usually only as a result of movement of lobsters from the surrounding area and often only as a temporary phenomenon. Lobster were found to move in from areas as far as 2.5 km away. The availability of food appears to be an important habitat variable at least for long term residence.

In Newfoundland, a long term monitoring program is underway on the Eastport Peninsula. While rocky bottom is clearly a preferred habitat type, lobster habitat has proven difficult to define since not all rocky bottom is occupied. Further, habitat per se is not a limiting factor for lobster, rather it is the high exploitation rate that prevails wherever the species is fished.

Lobsters feed on fish, dead or alive, mollusks, crustaceans and marine algae, using their claws to tear food into managable sized pieces. In turn they are eaten by wolffish, skates, cod and other fish species. Lobster are also cannibalistic.

Salmon (Salmo salar)

These anadromous fish spawn and spend their early years in fresh water. They move to sea in the spring of their third to fifth year as smolts. One to two years are spent at sea before the fish return as mature adults to spawn in their river of origin. One sea year fish reach 1.5 - 2.5 kg and are known as grilse. They do not undergo long distance migrations during their sea existence. The two sea year fish (salmon) reach 4 - 8 kg and represent the principal target of commercial and sports fisheries. Few rivers now support runs comprising more than 10% salmon (versus 90% grilse).

Two sea year fish undergo long distance migrations from their rivers of origin (Quebec, Maritimes, Maine, Newfoundland or Labrador) to northern feeding areas off Greenland. On their homeward migration, many mainland as well as Newfoundland bound fish follow the Newfoundland coastline. Details of these migration routes are not well known but the general pattern is as protrayed in Figure 11 (Porter, 1980).

In some cases salmon move from headland to headland, whereas others tend to closely follow the shoreline configuration once they encounter shallow water. It may be that salmon become more precise in following shorelines as they approach their river of origin.

There are no significant salmon rivers close to Greenspond Tickle. South West Arm Valleyfield had 5 salmon reported as angled in 1966 but there are no subsequent reports. The nearest significant river is to the south, about 20 km along the coastline at Indian Bay Brook. This river had an angling catch averaging 697 fish (weight 1200 kg) between 1969 and 1973 (Porter, Riche and Traverse, 1974).

The exposure of salmon to a series of fishery pressures in different geographic locations, some far removed from the river of origin, makes management of this valued species a tremendously difficult and controversial task.

Salmon in salt water feed on fish (such as herring, sand launce and capelin) and crustaceans (principally euphausiids and amphipods). Salmon are preyed upon by tuna, pollock, sharks and swordfish.

Capelin (Mallotus villosus)

Capelin are a pelagic schooling fish that spawn inshore along the beaches of Newfoundland between mid June and mid July. At least one large offshore spawning population occurs as well.

The eggs are laid as fish roll on sandy beaches. The demersal eggs incubate for 15 - 25 days when the pelagic larvae emerge to join the plankton. At an age of 3 - 4 months the fish can control themselves against the current. Fish mature at 2 - 3 years and do not usually survive beyond 5 years (Leim and Scott 1966)

Capelin feed on zooplankton (amphipods, copepods, euphausiids, decapods and shrimp). They are eaten by many species. Fish predators include cod, salmon, and dogfish. Seals, whales and many seabirds also feed on capelin.

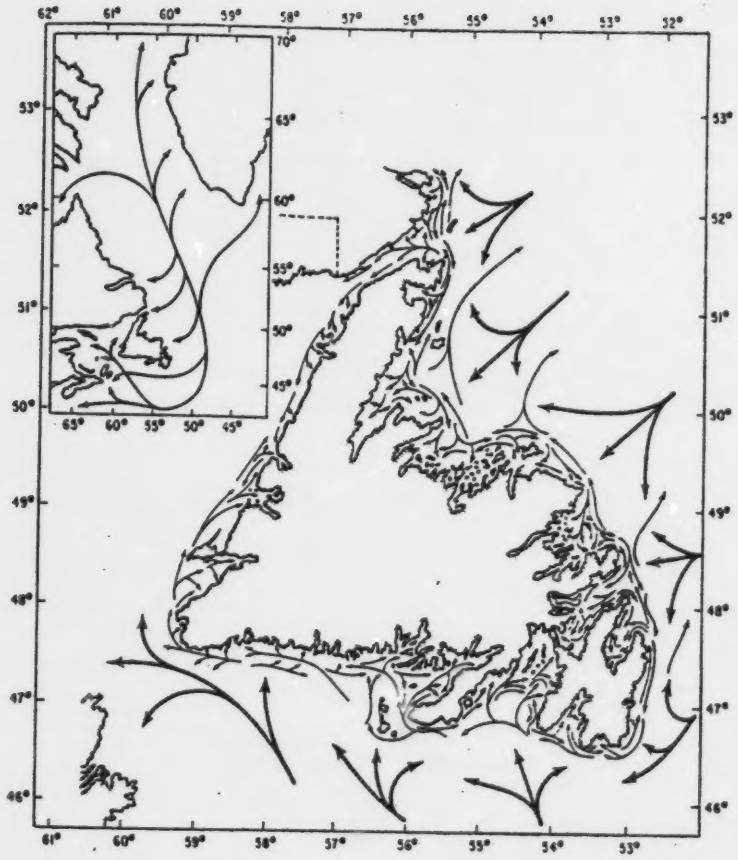

Figure 11 Migration paths of Atlantic salmon around the coasts of Newfoundland (from Porter 1980)

Herring (Clupea harengus)

The herring is a pelagic schooling fish that can occur in prolific numbers when a successful year class enters the population. Herring spawn either in spring or fall. On the northeast coast of Newfoundland herring spawn between mid April and mid July in shallow coastal waters (up to 10 m) often at the heads of bays or other inlets. The demersal, adhesive eggs incubate for 10 - 15 days after which the pelagic larvae enter the plankton to drift with the currents.

Herring are plankton feeders. They are preyed upon by most of the larger species of fish (cod, salmon, tuna).

Lumpfish (Cyclopterus lumpus)

Lumpfish are primarily bottom fish found on rocky bottom. Spawning occurs in shallow water during late spring. The eggs are laid in a mass that adheres to the substrate and is attended by the male until hatching (3 - 8 weeks). While the larvae are planktonic, they can adhere to the surface of material (eg mooring lines) with their sucker-like pelvic fins. Young-of-the-year settle out of the water column after 3 - 6 weeks.

Lumpfish feed on shrimp, amphipods, comb jellies and small fish. Seals eat large quantities of lumpfish (hence the name seal bait).

Mackerel (Scomber scombrus)

Mackerel are a moderately warm water pelagic fish that occur intermittently along the east coast of Newfoundland. They undergo an annual migration southward in the fall to wintering areas, and northwest in the spring and early summer, sometimes as far north as Newfoundland waters.

Spawning occurs May - July in the southern Gulf of St. Lawrence and off the Maine coast (not in Newfoundland waters).

Mackerel are planktonic feeders exclusively. They are in turn a food source for a wide variety of pelagic fishes.

Squid (Illex illecebrosus)

Squid have a one year life cycle, Following winter spawning in deep offshore waters, the adults die. Young squid move to shallow coastal waters in the summer (July - early August) and occupy the warm surface water layer after it has become too warm for cod.

The numbers of squid that appear along the coast can vary tremendously and this is reflected in commercial catches. Squid feed primarily on fish (caplein, groundfish) but also on invertebrates and benthos. Pothead whales feed almost exclusively on squid.

Fisheries

The region that includes the study area (Figure 2) is one of intensive inshore fishing. Fish plants at Valleyfield and Greenspond are supplied solely by longliners and open boats.

The communities in the area are fishing communities with little other source of employment. Provincial Fisheries operates a Marine Service Centre at Wesleyville.

Table 2 illustrates the number of licensed fishing vessels within fisheries statistical Section 10 (Figure 1). At present there are reported to be nine longliners (38 - 45') and 20 open boats ( 34') operating out of Greenspond, and 16 longliners (38 - 65') and 20 open boats fishing out of Badgers Quay, Wesleyville, Valleyfield and Pools Island (H Wicks, Provincial Fisheries, pers. com.).The apparent disparity in figures for smaller open boats may reflect differences in judgment as to what constitutes a "bona fide" fisherman.

Table 3 shows the number of registered fishermen by community. The single largest fishing community is Greenspond.

There are no statistics available for fishing gear.

The two fish plants in the area are both operated by Beothuck Fisheries Ltd. The Valleyfield plant was built and operated for some years by Federal Fisheries as an experimental operation before being turned over to private interests. The Greenspond plant started production in 1980 and its operation was assumed by Beothuck Fisheries in 1981.

The Valleyfield plant employs up to 400 workers. It has four cutting lines, seven plate freezers, three blast freezers and four ice machines. The plant can process (with one 8 hour shift) up to 68,000 kg/day of groundfish (cod) (90,000 kg/day of capelin).

The Greenspond plant is much smaller. It employs 40 - 50 people, has one cutting line, three plate freezers, and two ice machines.

The Valleyfield plant processed 11,100,000 kg. of fish in 1979, 7,574,000 kg. in 1980 (a year interrupted by a fishermen's strike) and 9,089,000 kg. in 1981. The 1981 production was broken down into 1,361,000 kg. capelin, 134,000 kg. herring ,770,000 kg. crab and the rest (5,800,000 kg.) groundfish. The Greenspond plant processd 1,134,000 kg. in 1981. Most of this was groundfish (cod, turbot, flounder, catfish). Capelin comprised 386,000 kg.

Both plants are fed by two sources: local vessels and collector boats. Neither plant has trawlers. The Valleyfield plant receives fish from local longliners, mostly out of Valleyfield and surrounding area, but also from as far away as Lumsden and even Musgrave Harbour. Two collector boats feed the Valleyfield plant, but on occasion are directed to Greenspond. Fish is collected from as far away as St Brendans to the south and Ladle Cove to the north (See Figure 1). About 320,000 kg. of fish are supplied to the Valleyfield plant by collector boats.

At Musgrave Harbour the company operates a feeder plant which fillets and ices fish. This fish is then transferred to Valleyfield for processing (NB - this fish is included in the throughput figures for the Valleyfield plant, but is not recorded as landings for Section 10).

## Table 2
## NUMBER OF VESSELS

| Community | Code | Length | 1972 | 1973 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|---|
| Newtown | (10-01) | 0-34' | 34 | 28 | 52 | 56 | 63 | 68 | 75 |
| | | 35-64' | 4 | 5 | - | - | - | 1 | 1 |
| | | 65-99' | - | - | - | - | - | - | - |
| | | 100'+ | - | - | - | - | - | - | - |
| Templeman | (10-02) | 0-34' | - | - | 1 | 1 | 1 | 2 | 3 |
| | | 35-64' | - | - | - | - | - | - | - |
| | | 65-99' | - | - | - | - | - | - | - |
| | | 100'+ | - | - | - | - | - | - | - |
| Pound Cove | (10-03) | 0-34' | 11 | 10 | 14 | 14 | 10 | 11 | 11 |
| | | 35-64' | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| | | 65-99' | - | - | - | - | - | - | - |
| | | 100'+ | - | - | - | - | - | - | - |
| Wesleyville | (10-04) | 0-34' | 36 | 44 | 61 | 54 | 59 | 63 | 59 |
| | | 35-64' | 7 | 7 | 4 | 4 | 3 | 5 | 4 |
| | | 65-99' | 1 | 1 | 1 | - | - | - | - |
| | | 100'+ | - | - | - | - | - | - | - |
| Brookfield | (10-05) | 0-34' | 5 | 8 | 7 | 5 | 7 | 9 | 6 |
| | | 35-64' | - | - | 1 | 1 | - | 1 | - |
| | | 65-99' | - | - | - | - | - | - | - |
| | | 100'+ | - | - | - | - | - | - | - |
| Badger's Quay | (10-06) | 0-34' | 13 | 19 | 26 | 27 | 36 | 38 | 31 |
| | | 35-64' | 4 | 3 | 3 | 2 | 4 | 6 | 3 |
| | | 65-99' | - | - | - | - | - | - | - |
| | | 100'+ | - | - | - | 2 | 2 | 1 | 1 |
| Pool's Island | (10-07) | 0-34' | 8 | 12 | 12 | 12 | 14 | 14 | 9 |
| | | 35-64' | - | - | - | - | - | - | - |
| | | 65-99' | - | - | - | - | - | - | - |
| | | 100'+ | - | - | - | - | - | - | - |
| Valleyfield | (10-08) | 0-34' | 3 | 8 | 13 | 12 | 14 | 15 | 28 |
| | | 35-64' | 3 | 1 | 4 | 4 | 7 | 7 | 14 |
| | | 65-99' | - | - | 1 | 1 | 1 | 1 | 1 |
| | | 100'+ | - | - | - | - | - | - | 1 |
| Greenspond | (10-09) | 0-34' | 39 | 44 | 56 | 50 | 63 | 73 | 78 |
| | | 35-64' | - | - | - | 2 | 3 | 6 | 7 |
| | | 65-99' | - | - | - | - | - | - | - |
| | | 100'+ | - | - | - | - | - | - | - |

Statistics & Computer Services Division
Economic Services Branch
Department of Fisheries & Oceans
St. John's, Newfoundland

Table 3

NUMBER OF FISHERMEN

| Community | Code | 1972 | 1973 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|
| Newtown | (10-01) | 50 | 42 | 67 | 68 | 83 | 101 | 102 |
| Templeman | (10-02) | - | 3 | 2 | 5 | 4 | 5 | 5 |
| Pound Cove | (10-03) | 24 | 24 | 21 | 20 | 17 | 18 | 21 |
| Wesleyville | (10-04) | 65 | 65 | 77 | 74 | 89 | 102 | 90 |
| Brookfield | (10-05) | 9 | 9 | 10 | 10 | 7 | 16 | 11 |
| Badger's Quay | (10-06) | 26 | 30 | 44 | 49 | 60 | 70 | 53 |
| Pool's Island | (10-07) | 12 | 13 | 16 | 15 | 25 | 21 | 16 |
| Valleyfield | (10-08) | 19 | 20 | 24 | 35 | 50 | 66 | 96 |
| Greenspond | (10-09) | 55 | 53 | 75 | 71 | 95 | 108 | 121 |

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St. John's, Newfoundland

The plant handles crab landings from three longliners that are crab fishing full time. In season about 100 people work at processing crab.

The Greenspond plant is served by vessels out of that community and on occasion receives fish from one of the collector boats. In 1981, 160,000 kg. fish were supplied by collector boats.

The proportion of fish supplied to the Valleyfield plant varies with the season. Early in the season 75 - 80% of the plant input is from the local Valleyfield area boats. Later on, up to 50% of the fish is from small open boats from outside the local area. In the fall, all the fish comes from longliners. Overall about 60% of the plant's fish comes from longliners. These are essentially gill netters operating 10-25 km from the plants.

Neither plant handles salmon. The small quantity caught is mostly consumed by local trade. Lobster are handled by buyers who purchase direct from fishermen.

Fish landing for Section 10 (see Figures 12 and 13) were provided by Federal Fisheries (L. Feltham, Economic Services Branch). It is not possible to determine the actual location of catches, or the proportion taken in a particular area. These figures do serve however to illustrate the importance of fishing to the economy of the area, and to indicate relative importance of each species.

A site visit was made on May 9 - 10, 1982 and interviews were held with several individuals to obtain information on the pattern of fishing in the Greenspond Tickle area. Those interviewed were:

H. Wicks - Provincial Fisheries, Wesleyville
A. Wicks - Chairman, Fishermens Committee, Badgers Quay
R.Granter - Mayor, Greenspond
N. Sturge - Fishery Officer, Valleyfield
A. Coward - Fisherman, Greenspond

Also subsequently interviewed by telephone were Michael Bragg, Greenspond and Boyd Way, Beothuck Fisheries, Valleyfield. Based on the information provided, the following decription of the local fishery was constructed.

The longliner fishery is a gill net fishery mainly for groundfish in relatively offshore waters, There are three vessels licensed to fish crab which are taken in relatively deep water. Some seining of caplin, herring and, occasionally mackerel occurs inshore. The smaller open boats pursue lobster, salmon, squid and groundfish principally. Greenspond fishermen cover an area from Shoe Cove Point north to Loo Cove (Figure 2). Valleyfield and area fishermen fish from Loo Cove north. The boundary is more related to steaming distance than any enforced rule, however the drawing for (salmon and codtrap) berths reflects this boundary.

Fishing activity in Pond Tickle is not intensive, except for lobster. The Tickle is used as a sheltered passage for open boats and longliners on their way to and from the Valleyfield area.

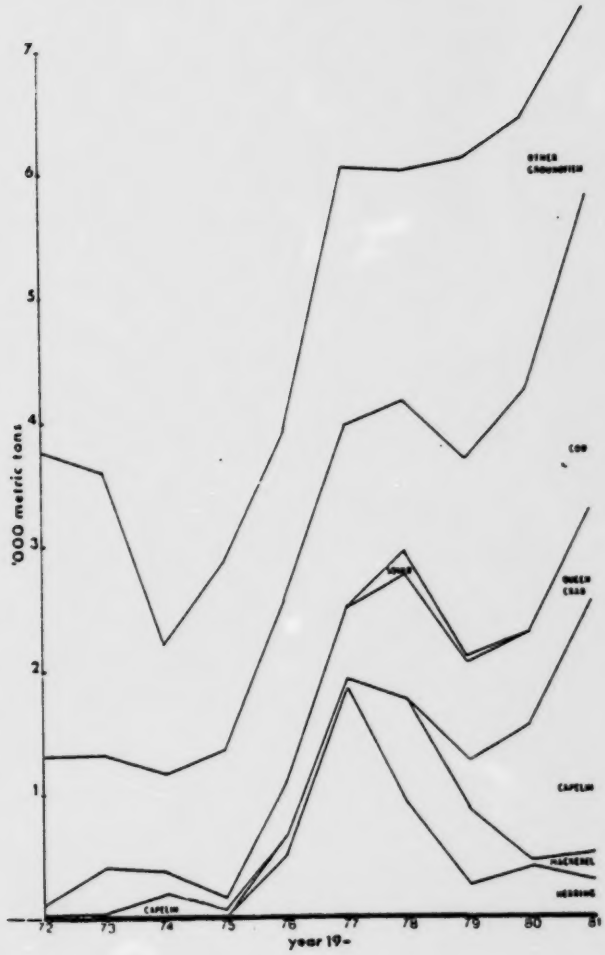


Figure 12 Fish landings by weight for statistical section 10

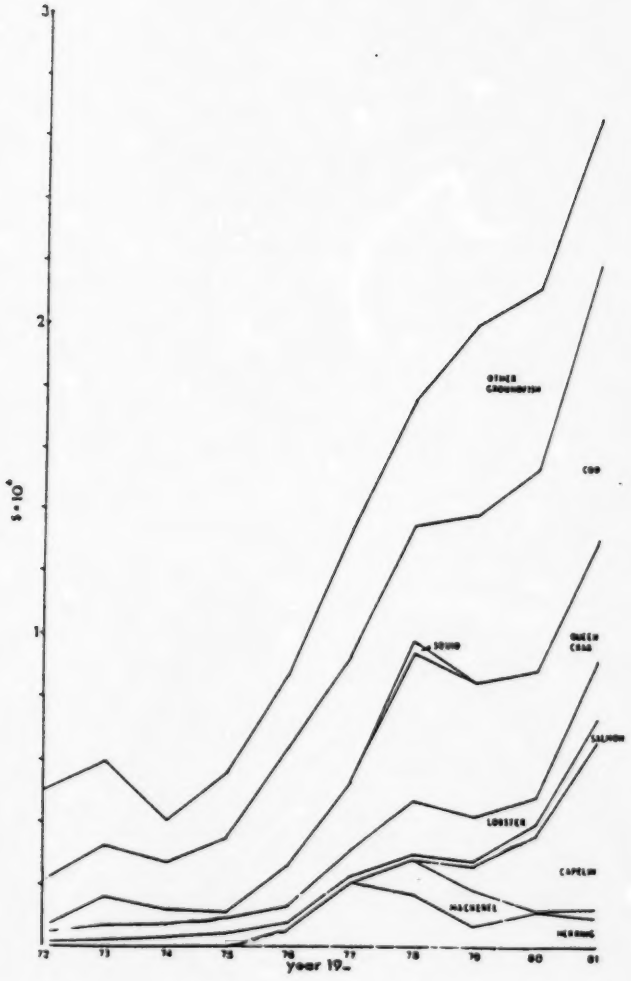


Figure 13 Fish landings by value for statistical section 10

Salmon

Any location where a net can be set from the shore or a rock above water is a drawn berth. Figure 14 shows salmon net location reported for the area illustrated. Not all berths are occupied every year and some berths are considered prime, whereas others are secondary.

The prime berths are off the northeast side of Greenspond as far as Hardings Head and off the islands southeast of Greenspond (Puffin Island, Newell Island, Copper Island).

In 1981 only one net was set in the Tickle. It was placed in Shamblers Cove for one week. There are no salmon nets reported in the Tickle this year. Salmon catches in recent years have been generally low in the area.

Cod

The trap fishery has been very poor in recent years and many designated trap berths (Figure 15) are not used. Only 3 - 4 berths are fished regularly. Fishermen tend to use trawls and hand lines later in the season.

Gill nets are set in the area south of Greenspond near Maiden Island, and farther offshore to the southeast (mainly by longliners).

Lobster

A large number ( 1000) of lobster pots are fished in the area as shown in Figure 16. Pots are set almost anywhere shallow water allows. Early in the season the pots are set in relatively deeper water up to 12 fathoms. Later the pots are moved into shallower water. Areas of heavy use include Loo Cove, Shamblers Cove and Broad Cove.

Herring

The fishery occurs from April 1 to the end of June, and again in September if the quota allows. Herring are taken in gill nets by small boat fishermen and in seines by longliners. Many of the herring nets are set in salmon berth locations. A large mumber are set in the area of Loo Cove.

A limited effort has been made to seine herring and mackerel in the Tickle (See Figure 17).

Capelin

In very recent years this has become an important species. Traditionally capelin occurred north of Shamblers Cove and particularly in Newell Island Sound. It is now reported that few capelin pass through the Tickle but they do pass through the Newell Island Sound area and are seined southwest of the sound (Figure 17).

Mackerel

These fish are sporadic in occurrence, however there has been some seining of mackerel reported in the southern end of Greenspond Tickle off Broad Cove.

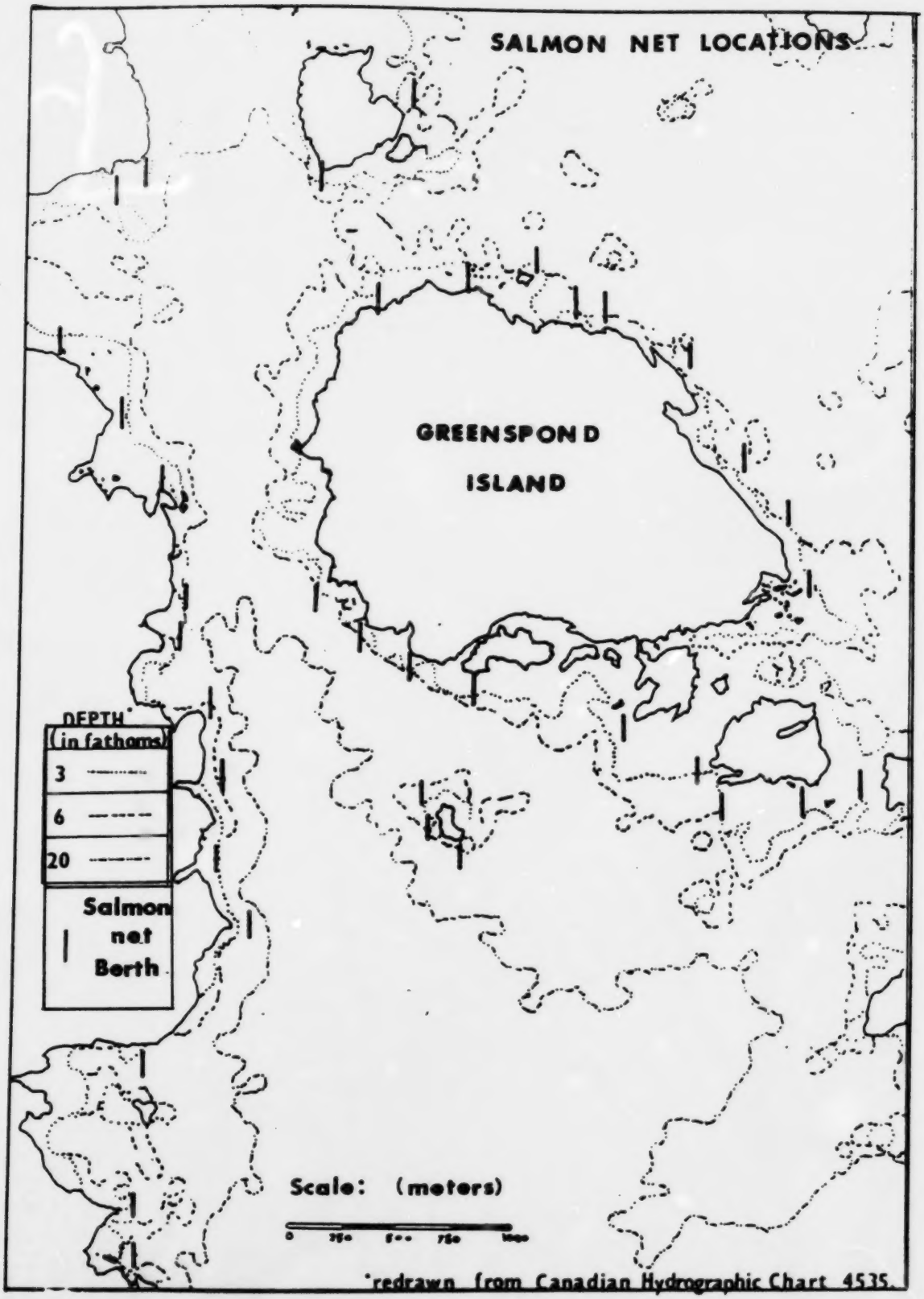


Figure 14 Salmon net locations

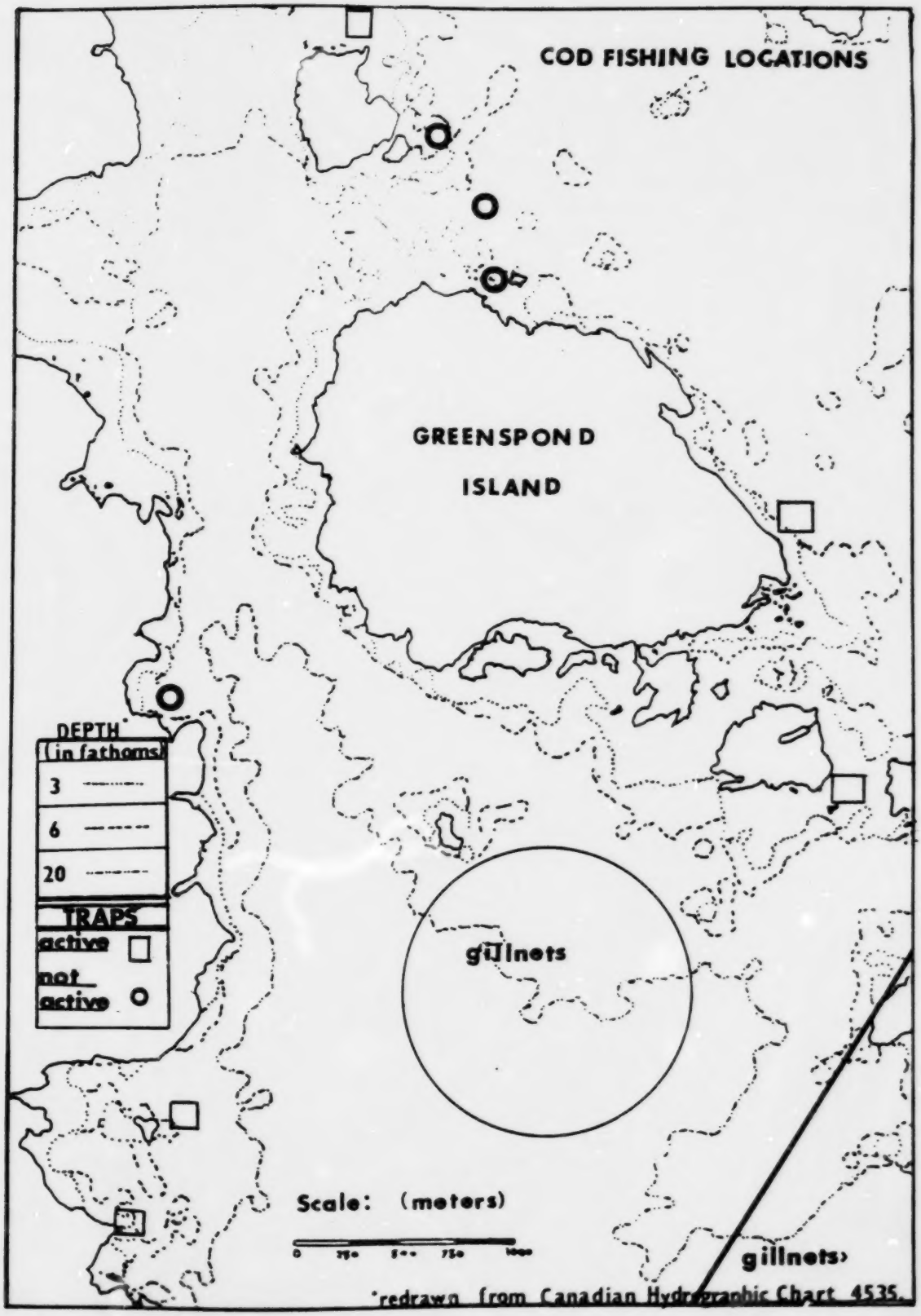


Figure 15 Cod fishing locations

Squid

When the squid run inshore they are jigged from small open boats, mainly for use as bait, however in recent years a Japaneese food market for dried squid has developed. Local squid jigging locations include Loo Cove, Broad cove and the area between Maiden Island and Greenspond Island (Figure 17).

Lumpfish

Lumpfish are taken in large mesh nets as they move inshore to breed in early summer. The fishery is for the roe of females. Lumpfish nets were set off Partridge Island Tickle during 1975 and 1978 (Figure 17). However there were few fish taken. There is no directed lumpfish fishery at present. Lumpfish have also been taken as a by-catch in cod traps.

Other species

Turbot, flounder, and catfish are taken offshore by trawls and gillnets. However, none of the species occur in the Tickle area.

Some experimental drags for scallops are reported to have been carried out in the Tickle several years ago (H. Wicks). There were no significant number of scallops taken.

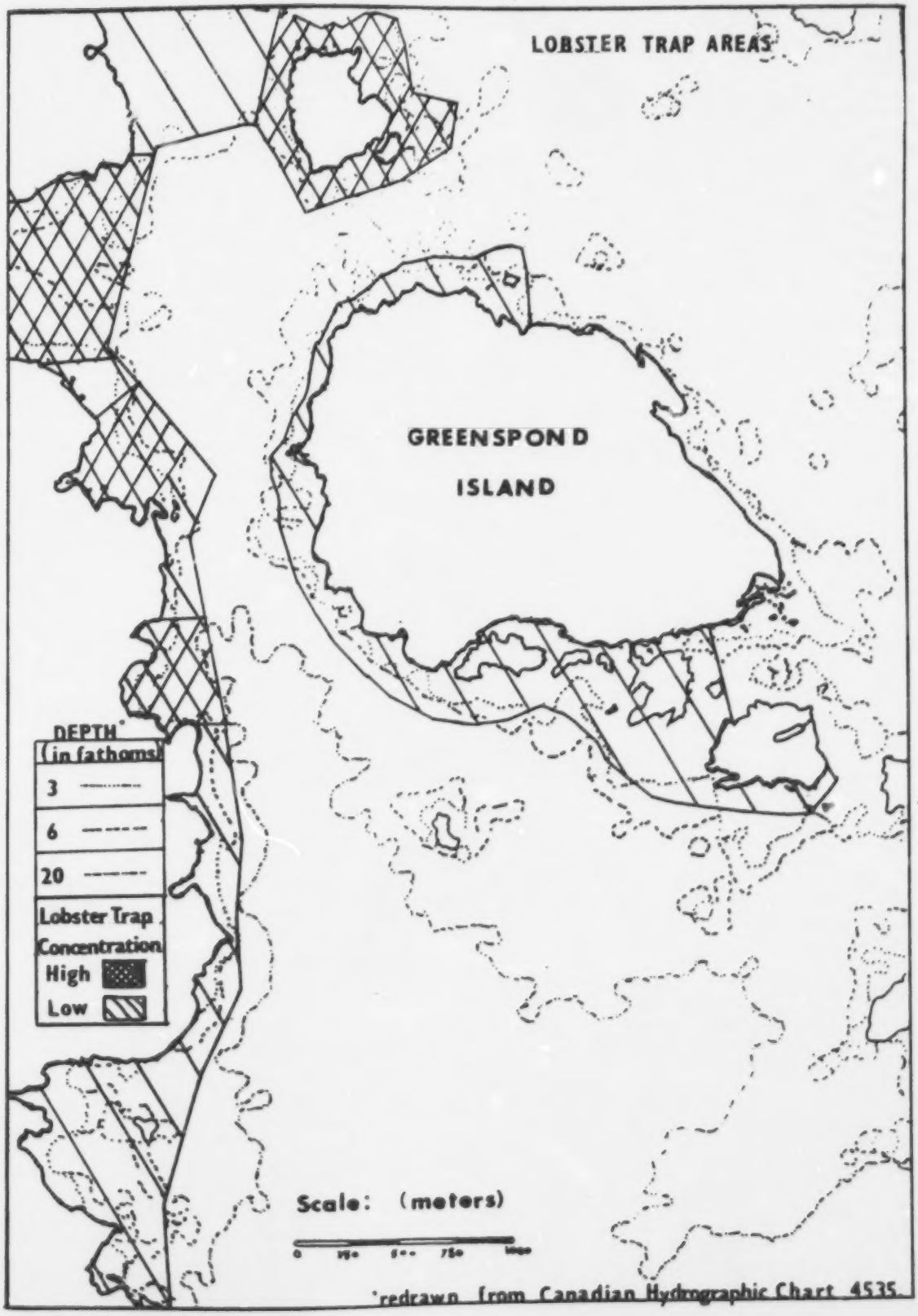


Figure 16 Lobster trap areas

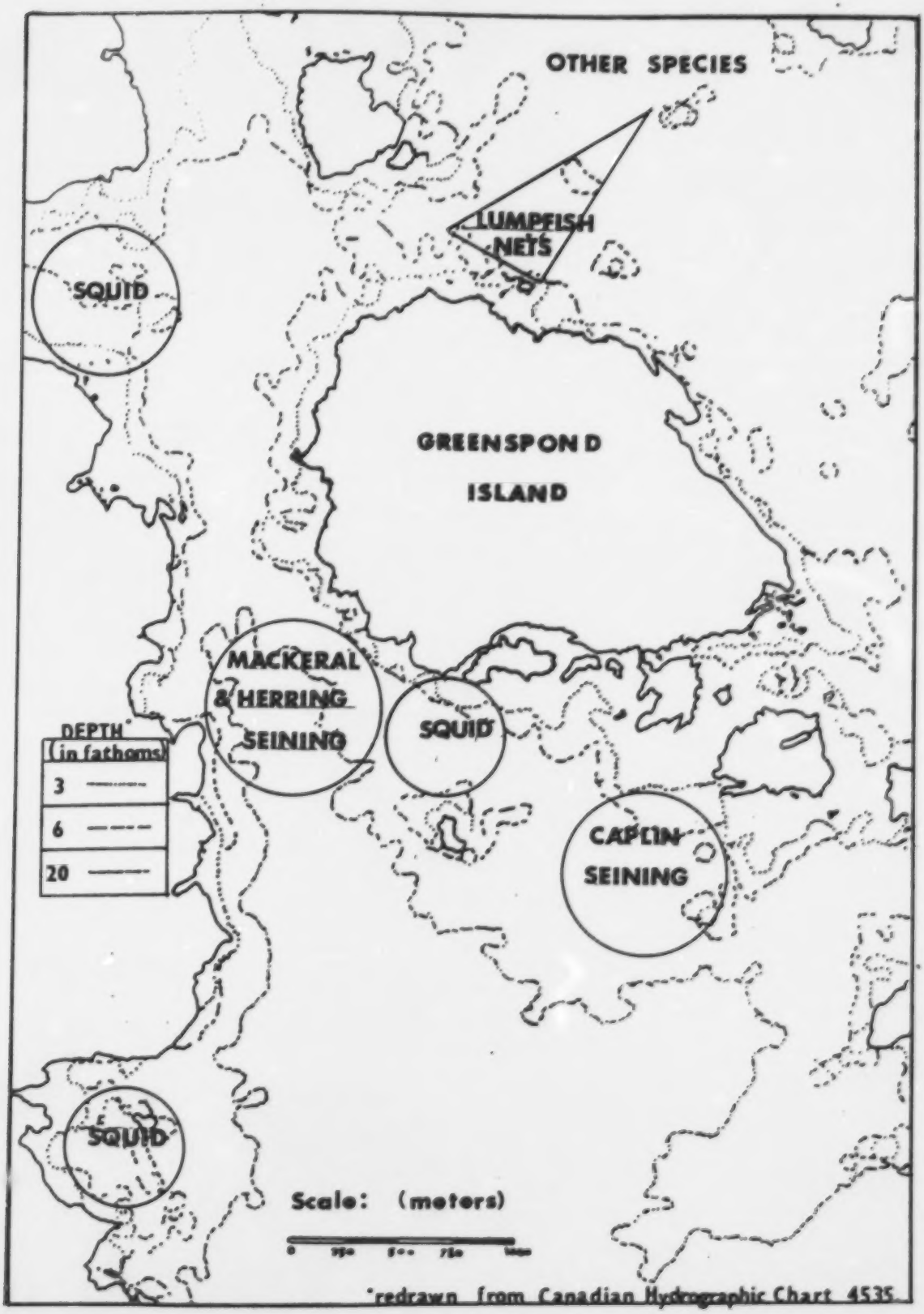


Figure 17 Locations of other species

# IMPACTS

## PHYSICAL OCEANOGRAPHY

### Crosss-sectional Displacement by the Causeway

The proposed causeway across Greenspond Tickle will fill in the whole cross-sectional area except for a bridge at the east end of the causeway near Greenspond Island. This opening will be approximately 27 m wide and 8 m deep at the deepest point to allow boats to pass through. The opening will have and angle of 30° with the horizontal and a cross-sectional area of 109 $m^2$. The area filled with quarry rock will consist of 8551 $m^2$ which is approximately 99% of the total cross-sectional area. Therefore the present flow through Greenspond Tickle will be almost completely blocked off except for current through the opening and seepage through the porous quarry rock.

### Changes in Wind Driven Flow

The construction of a causeway across Greenspond Tickle will act as a barrier to the wind driven flow, and will cause changes to the present current system. A numerical model was developed to predict these changes in flow patterns and to estimate the area which would be affected. The model was based on the momentum equation and quadratic stress laws. Neglecting eddy viscosity, the equation of motion for the flow along the longitudinal axis of the Tickle can be written as

$$dV/dt = -g\ \partial\xi/\partial y - fU + (1/\rho)\partial F/\partial z$$

where $\xi$ is the coordinate of the free surface
$f$ is the Coriolis parameter
and $F$ is the frictional stress
vertically integrating this equation over the water depth yields

$$\partial V/\partial t + U\,\partial V/\partial x + V\,\partial V/\partial y = -g\ \partial\xi/\partial y - fU + (F_s - F_b)/\rho d$$

where $F_s$ and $F_b$ are the frictional stresses at the surface and the bottom, respectively.

Since Greenspond Tickle has a width of only 0.62 km, the Coriolis force can be neglected. The nonlinear field accelerations will also be small compared with the surface and bottom friction terms. The equation of motion now reduces to

$$\partial V/\partial t = -g\ \partial\xi/\partial y + (F_s - F_b)/\rho d.$$

The surface stress $F_s$ was taken as the usual wind condition $F_s = \rho_a C_d W^2$ where $\rho_a$ = air density, $W$ = wind speed, and $C_d$ = Drag Coefficient. The bottom stress was parameterized by the quadratic stress law $F_b = g\rho V^2/C^2$ where C is the Chezy friction coefficient. This coefficient is a function of depth and described by Dronkers (1964) as having the value $C = g^{1/2}\ k^{-1}\ \ln 12d\ a_o$ where $a_o$ depends on the height of the irregularities on the bottom, d is the water depth, and k is the Von Karman constant with a value of 0.4.

The surface wind stress was calculated for winds varying from 10 km/hr to 100 km/hr. The values are given in Table 4. The wind stress produced a wind driven current which caused a pile up of water against the causeway usually referred to as a set-up. For winds from the south and south-southeast, the surface elevations on the south side of the causeway were

Table 4. Calculated surface elevations and reverse velocities in Greenspond Tickle south of the causeway.

| Wind Speed (W) (km/hr) | Surface Stress ($F_s$) ($N/m^2$) | Surface Elevation ($\xi$) (cm) | Bottom velocity (V) (cm/sec) |
|---|---|---|---|
| 10 | 0.0185 | 0.3 | 9 |
| 20 | 0.0741 | 1.2 | 19 |
| 30 | 0.1670 | 2.8 | 28 |
| 40 | 0.2690 | 4.9 | 37 |
| 50 | 0.4630 | 7.7 | 46 |
| 60 | 0.6670 | 11.0 | 56 |
| 70 | 0.9080 | 15.0 | 65 |
| 80 | 1.1900 | 19.7 | 74 |
| 90 | 1.5000 | 24.8 | 83 |
| 100 | 1.8500 | 30.6 | 93 |

calculated using a length scale of 50 km, the approximate distance across Bonavista Bay. The depth of the wind driven surface layer was taken as the usual 30 meters. For increasing wind stress, the surface elevations were found to vary from 0.3 cm during a 10 km/hr wind to 30.6 cm during a 100 km/hr wind. These sea surface slopes will produce currents near the bottom which flow in an opposite direction to the wind driven surface currents. After steady state has been reached, and using a water depth of 26 meters, the velocities of the reverse flow were calculated to vary from 9 cm/sec to 93 cm/sec in the Tickle on the south side of the causeway, for winds of 10 km/hr to 100 km/hr.

For winds from the north-northeast and northeast, the water set-up will occur on the north side of the causeway. The results for the surface elevations and bottom velocities are given in Table 5 . The length scale was taken as the distance from the study site to Cape Freels, and the water depth was taken as 12 m , a representative depth for the shallow area northeast of Greenspond Island. On the north side of the causeway, the surface elevations varied from 0.4 cm to 39.8 cm and the reverse velocities near the causeway varied between 8 cm/sec and 83 cm/sec.

The average wind speed is approximately 20 km/hr for this area. This will give a set-up of 1.6 cm and a reverse flow of 17 cm/sec on the south side of the causeway, and a set-up of 1.2 cm and a reverse flow of 19 cm/sec on the north side.

Using the cross-sectional dimensions of the Tickle and the conservation of mass, the reversal in flow was calculated to occur at a depth of 10 m on the south side of the causeway during winds from the south-southeast of 20 km/hr and 40 km/hr. On the north side of the causeway, the reversal depth was calculated as being 7 m for wind speeds from the northeast of 20 km/hr and 40 km/hr. This decrease in depth is due largely to the shallow water on both sides of Partridge Island which tends to restrict the volume of the inflowing wind driven water mass. For both cases, the wind driven currents in the top layer were taken from the measurements from the current meter since these values were judged as being the most representative. Moreover, current profiles at three locations across the Tickle showed that there was little variation with depth and location over a water depth of 20 m, in the absence of a causeway.

The reversal depths calculated for Greenspond Tickle compared well with measurements in other locations where reverse currents have been measured as a result of wind driven surface currents. For instance, Murray (1972) measured reverse currents to occur at approximately mid-depth in a water depth of 15 m on the shelf east of the Mississippi River Delta, as a result of wind driven currents against a coast. Petrie and Drinkwater (1978) found a similar situation in St. Georges Bay after the construction of the Canso Causeway. With a depression in water level of about 5 cm near the causeway, the flow at 20 m in St. Georges Bay was reversed in direction to the current measured at 5 m.

Table 5. Calculated surface elevations and reverse velocities in Greenspond Tickle North of the causeway.

| Wind Speed (W) (km/hr) | Surface Stress ($F_s$) ($N/m^2$) | Surface Elevation ($\xi$) (cm) | Bottom velocity (V) (cm/sec) |
|---|---|---|---|
| 10 | 0.0185 | 0.4 | 8 |
| 20 | 0.0741 | 1.6 | 17 |
| 30 | 0.1670 | 3.6 | 25 |
| 40 | 0.2960 | 6.4 | 33 |
| 50 | 0.4630 | 10.0 | 41 |
| 60 | 0.6670 | 14.4 | 50 |
| 70 | 0.9080 | 19.5 | 58 |
| 80 | 1.1900 | 25.6 | 66 |
| 90 | 1.5000 | 32.3 | 74 |
| 100 | 1.8500 | 39.8 | 83 |

In order to predict the lateral extent of the changed current system due to the causeway, the currents above and below the reversal depth were calculated. A horizontal grid with square sizes of $9 \times 10^4$ $m^2$ was used in the calculations. The area south of the causeway was divided into 50 grids with an open boundary to the south. The region north of the causeway consisted of 12 grids bounded by the bathymetry restrictions. The velocities in each grid were calculated by the model using the mean water depth in each grid, the reversal depth, and the conservation of mass.

For the area south of the causeway, the velocities at depths of 5m and 13m are shown in Figures 18 to 22 . In these figures the winds are from the south-southeast with speeds varying from the average value of 20 km/hr to extreme conditions of 100 km/hr. The area affected by the causeway increased with wind magnitude. Figure 18 shows that for an average wind speed of 20 km/hr the effects extend to the cross-sectional area bounded by the southern ends of Broad Cove and Greenspond Island. For a 40 km/hr wind, the effects extend to Maiden Island (Figure 19) and for strong conditions of 100 km/hr the effects reach as far as Fox Head (Figure 22). When the winds are from the south to south-southeast, the area north of the causeway will be protected from the wind. This means that the flow will be mainly tidal, resembling the condition during no winds. Temperature fluctuations of 3 to 4 Celsius degrees over a few hours will no longer occur and the water will maintain a temperature similar to that currently found during wind conditions from the north to northeast.

Figures 23 to 27 show that for winds from the north-northeast to northeast, the current changes extend to Partridge Island for all wind conditions. When the wind is from these directions, the water to the south of the causeway may be affected by a depression in sea level with the effects being less than during the times when the winds are from the south to south-southeast. The water in the area south of the causeway will no longer have large variations in water temperature over a short time interval, and will maintain a slightly colder temperature than it currently experiences.

Velocities in the Bridge Opening

The cross-sectional area of the bridge opening is about 1% of the total cross-sectional area of the Tickle. Since this area is small, the volume transport through the Tickle is insignificant compared with the total transport. Even though the cross-sectional area and volume transport are small, the current velocities can be considerable when the water level on one side of the causeway is higher than the water level on the opposite side.

From the calculations for the effects of wind driven flow, the elevation was found to vary from 0.3 cm to 40 cm depending on wind speed. Assuming a frictionless flow through the constriction, the Bernoulli equation was used to calculate the velocity of the current in the bridge opening and of the current jet on the opposite side. This equation gives $1/2U_2^2 = 1/2\ U_1^2 + g(\Delta H)$ where $U_1$ is the velocity of the wind driven current, $U_2$ is the velocity of the current in the opening, and H is the difference in water levels.

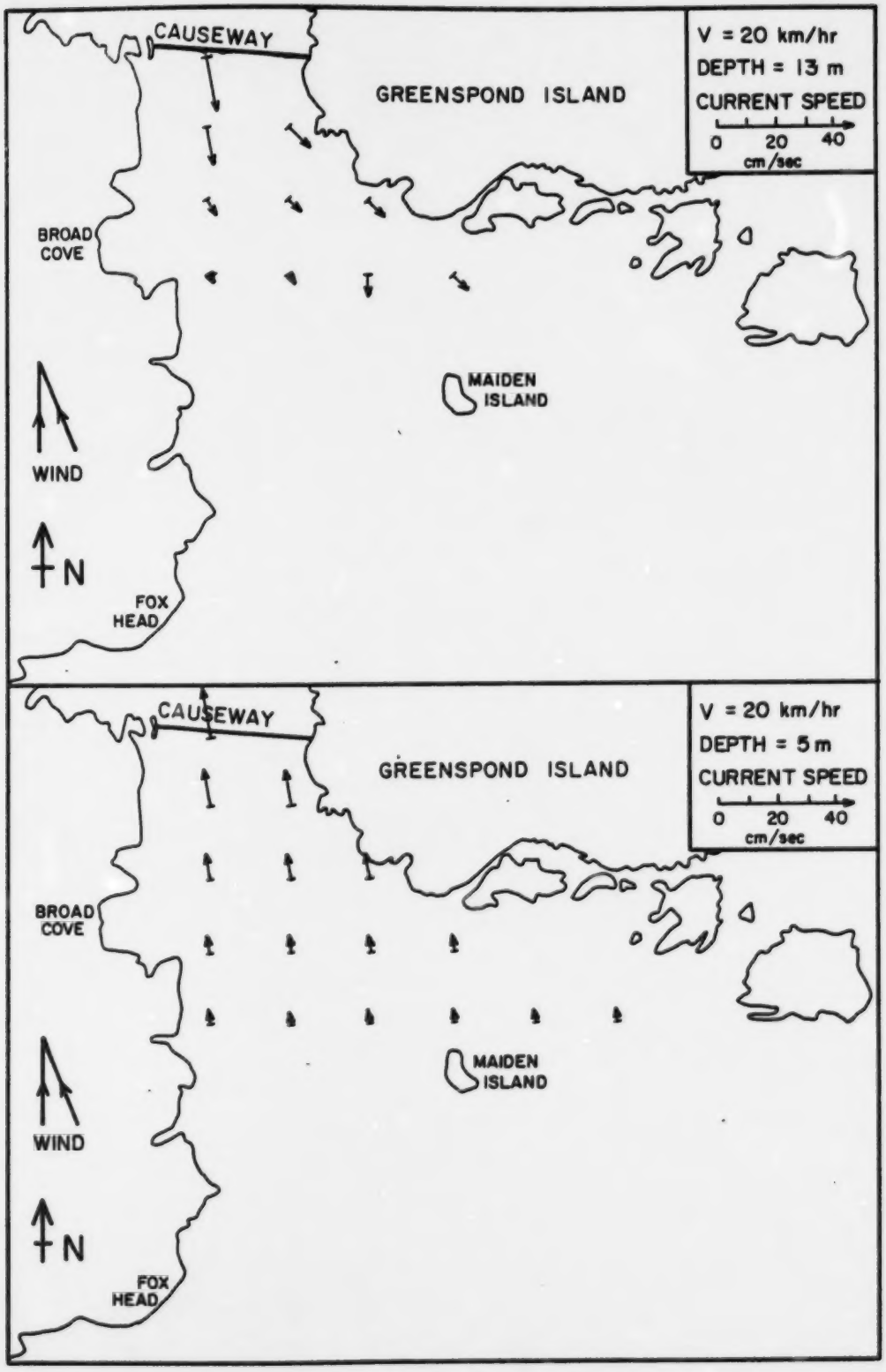


Figure 18 Currents on south side of causeway during winds from the south to south-southeast of 20 km/hr

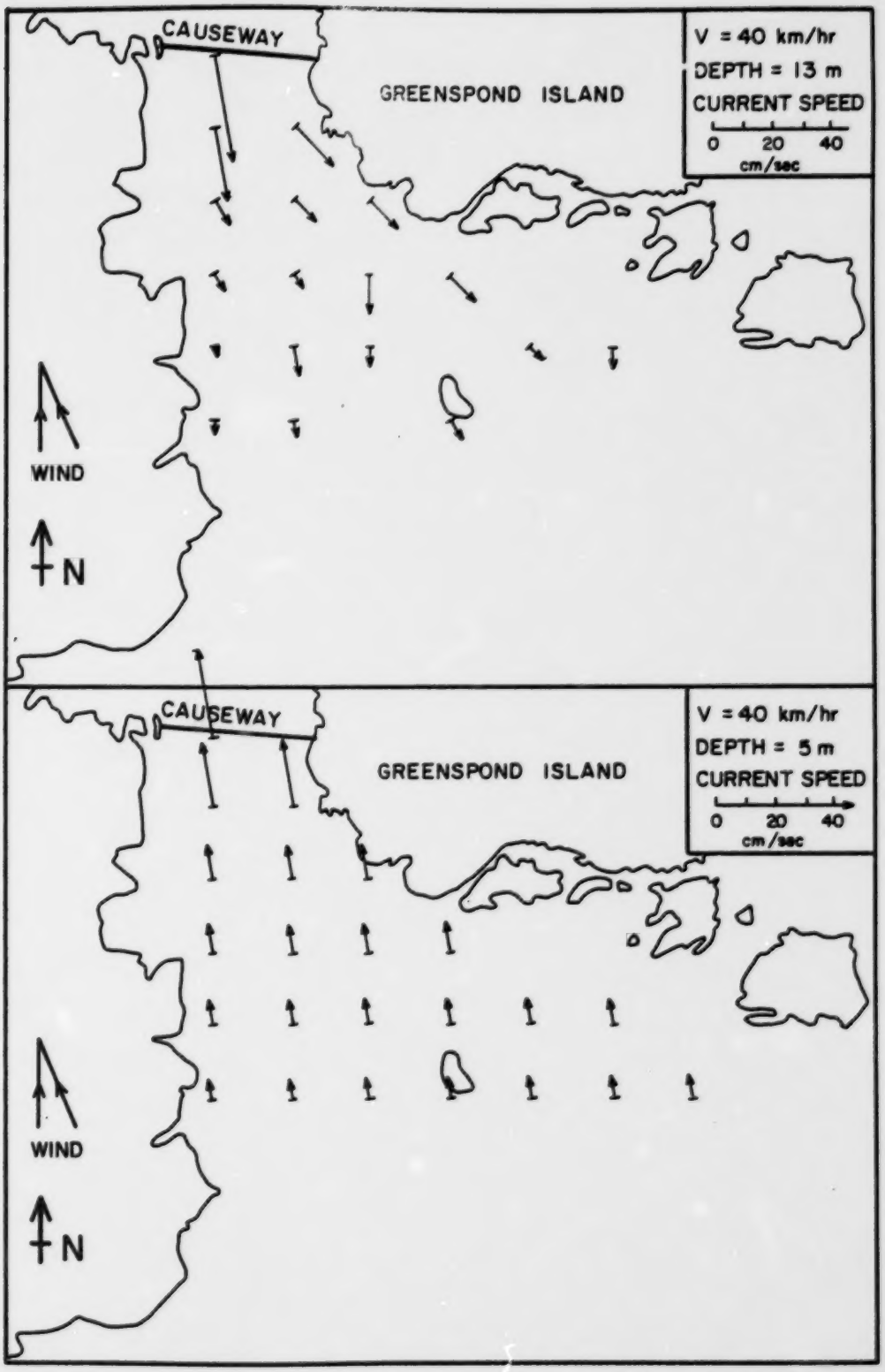


Figure 19 Currents on south side of causeway during winds from the south to south-southeast of 40 km/hr

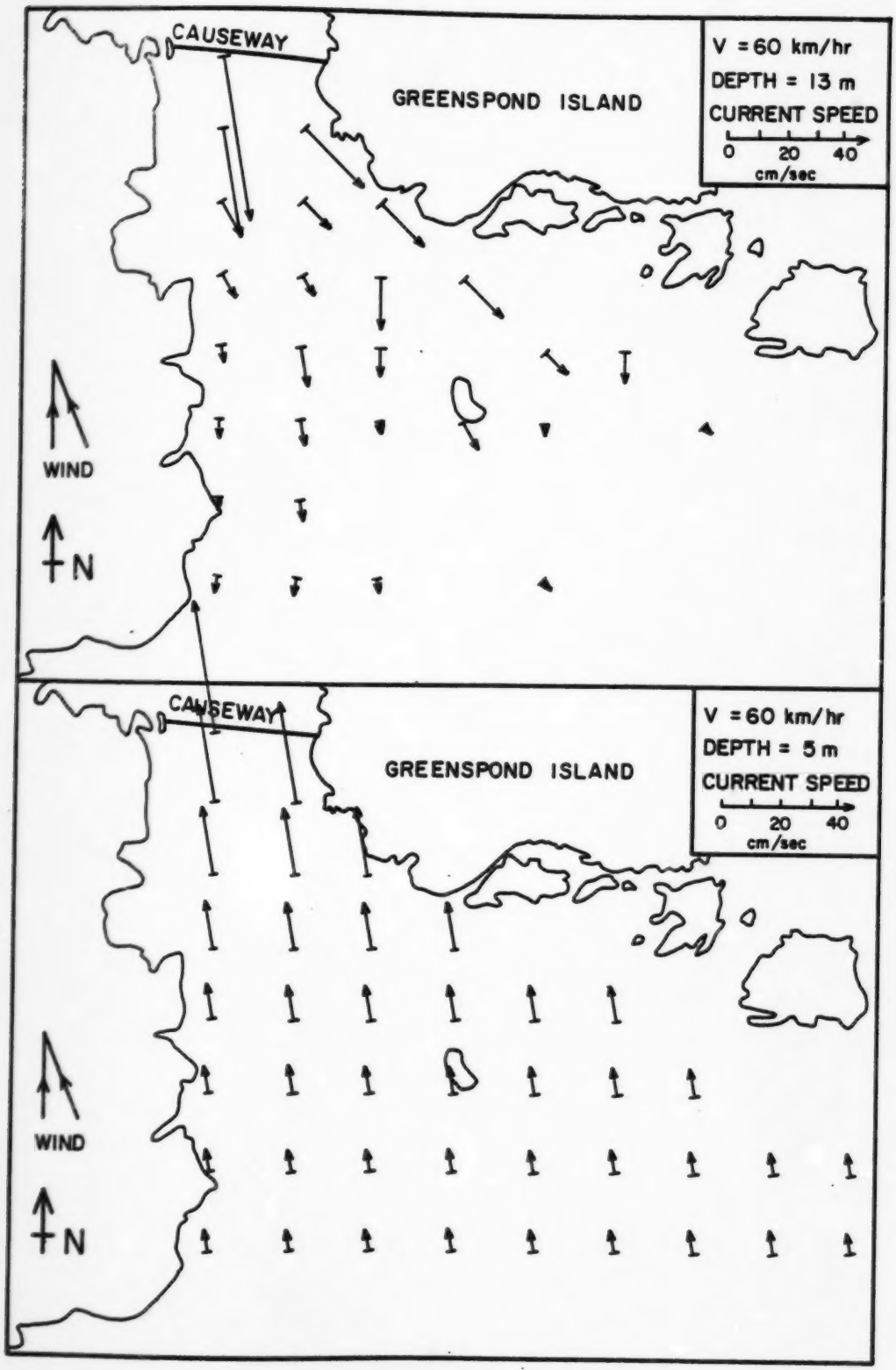


Figure 20 Currents on south side of causeway during winds from the south to south-southeast of 60 km/hr

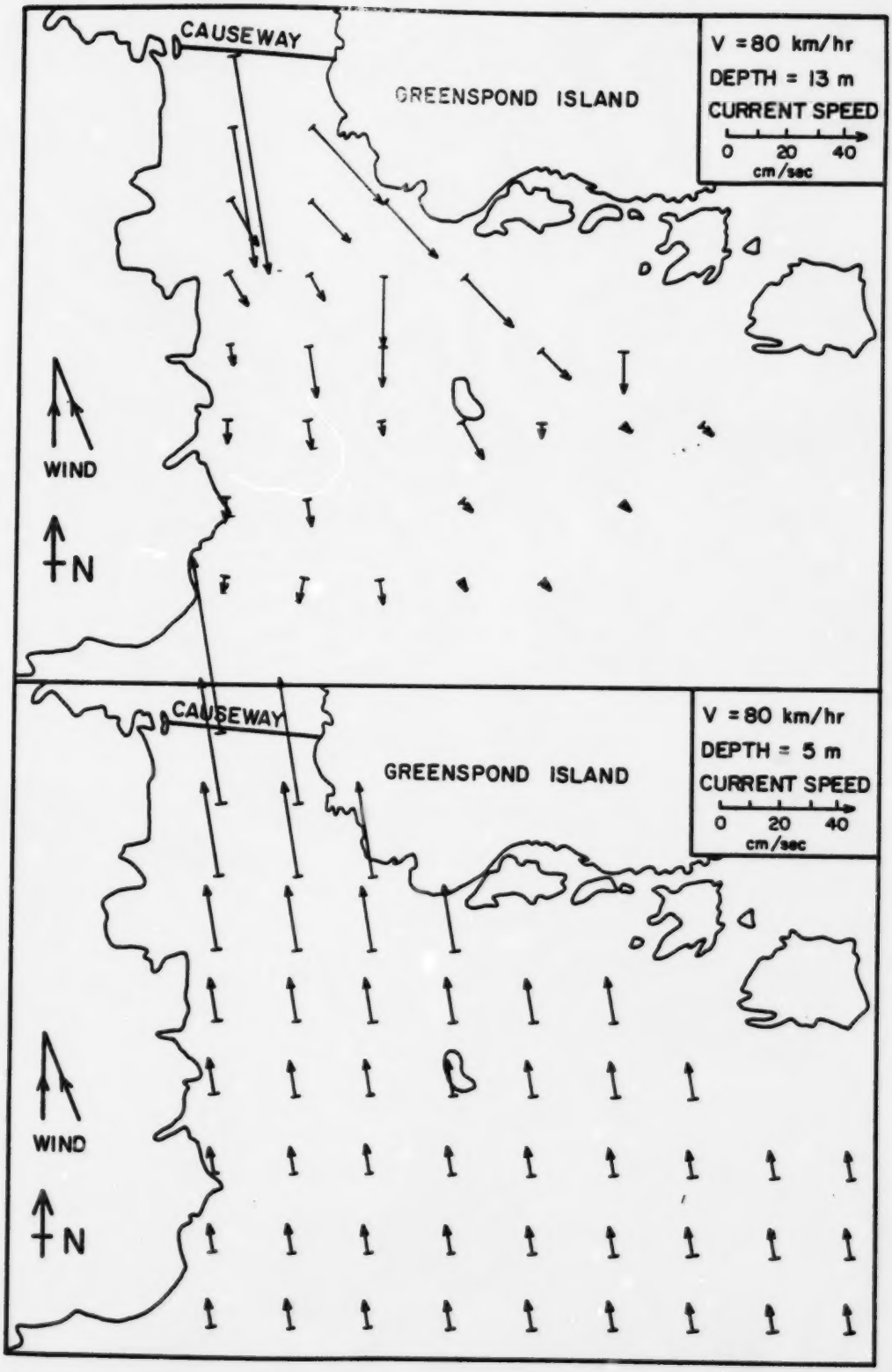


Figure 21 Currents on south side of causeway during winds from the south to south-southeast of 80 km/hr

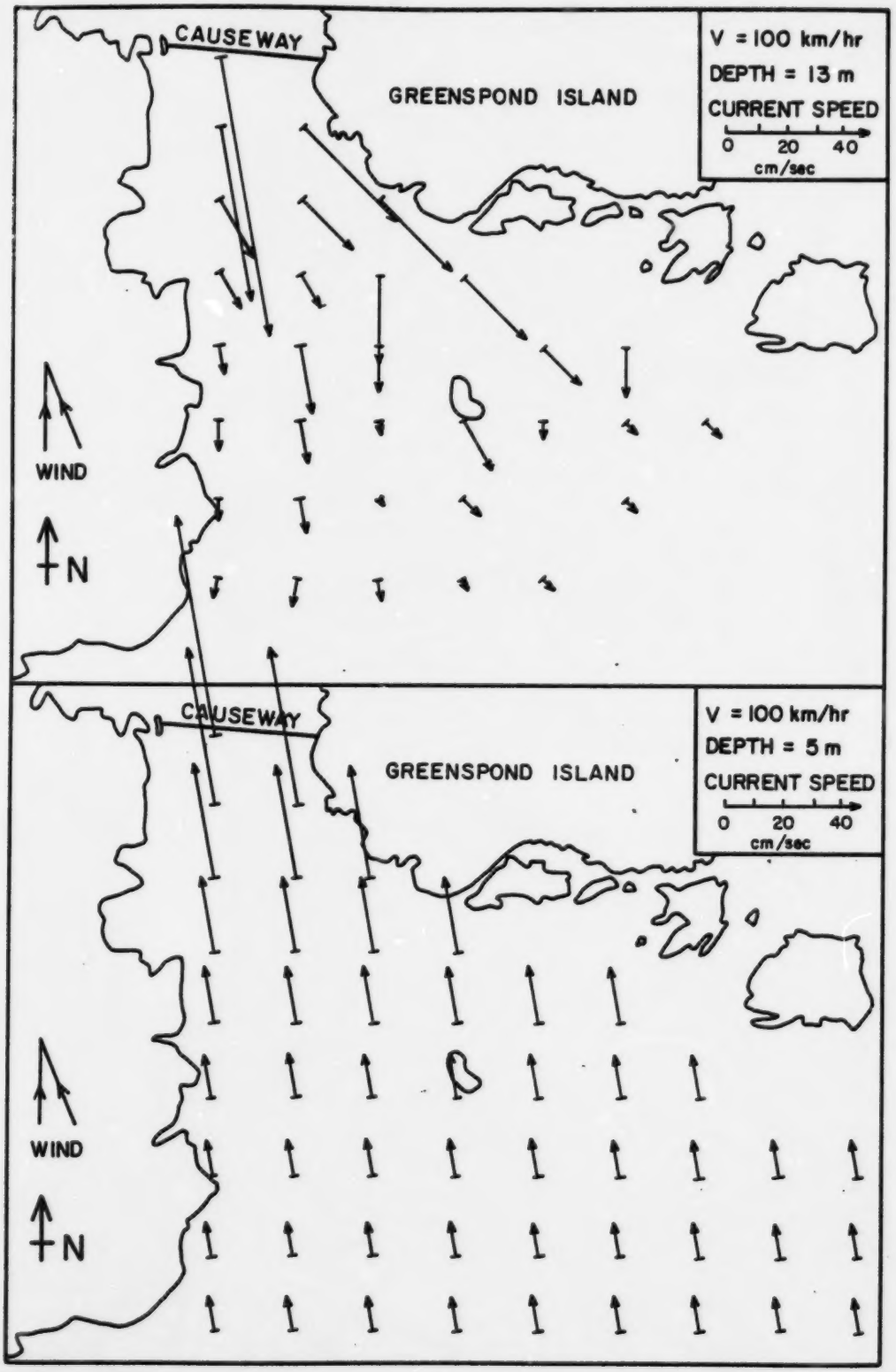


Figure 22 Currents on south side of causeway during winds from the south to south-southeast of 100 km/hr

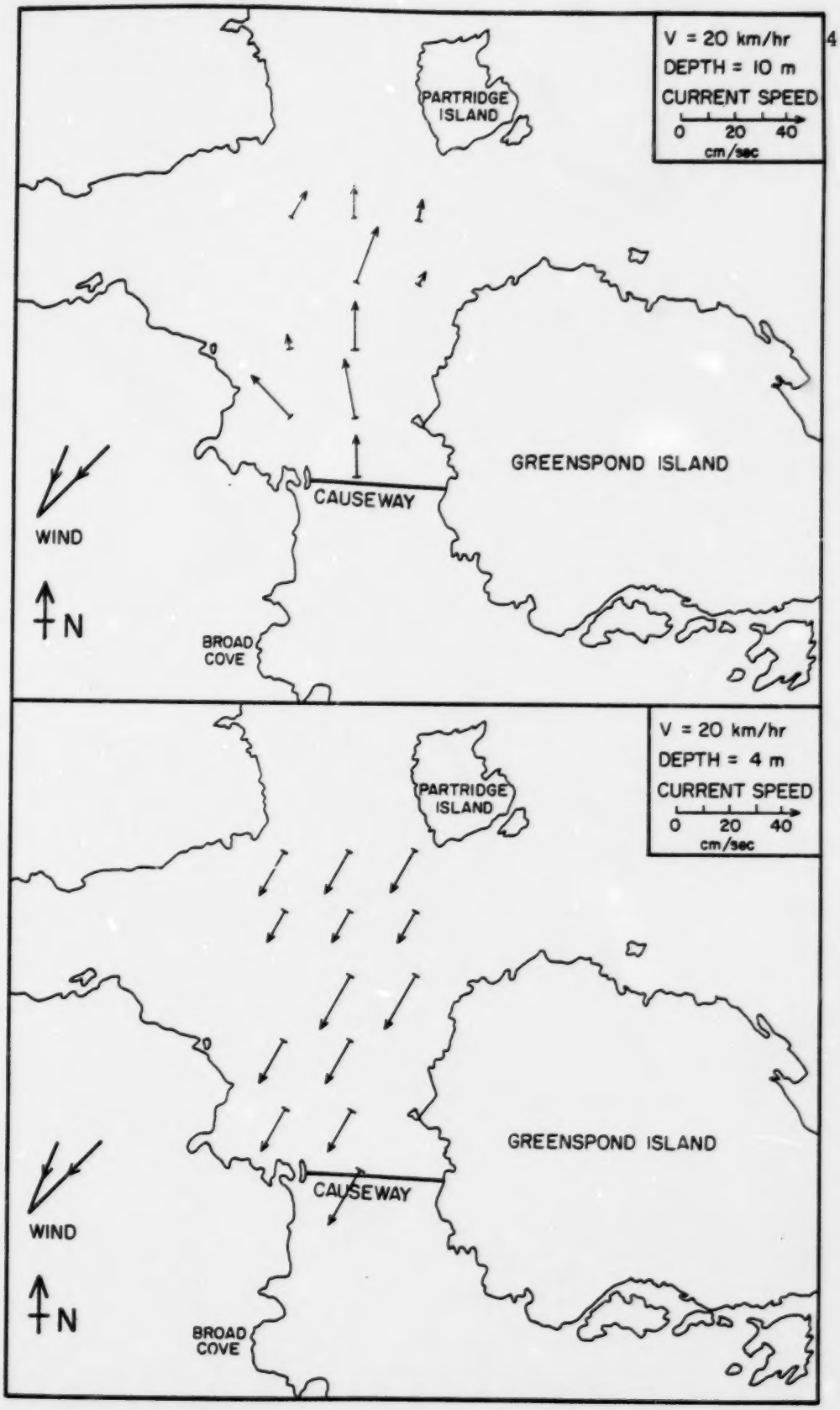


Figure 23 Currents on north side of causeway during winds from the north-northeast to northeast of 20 km/hr

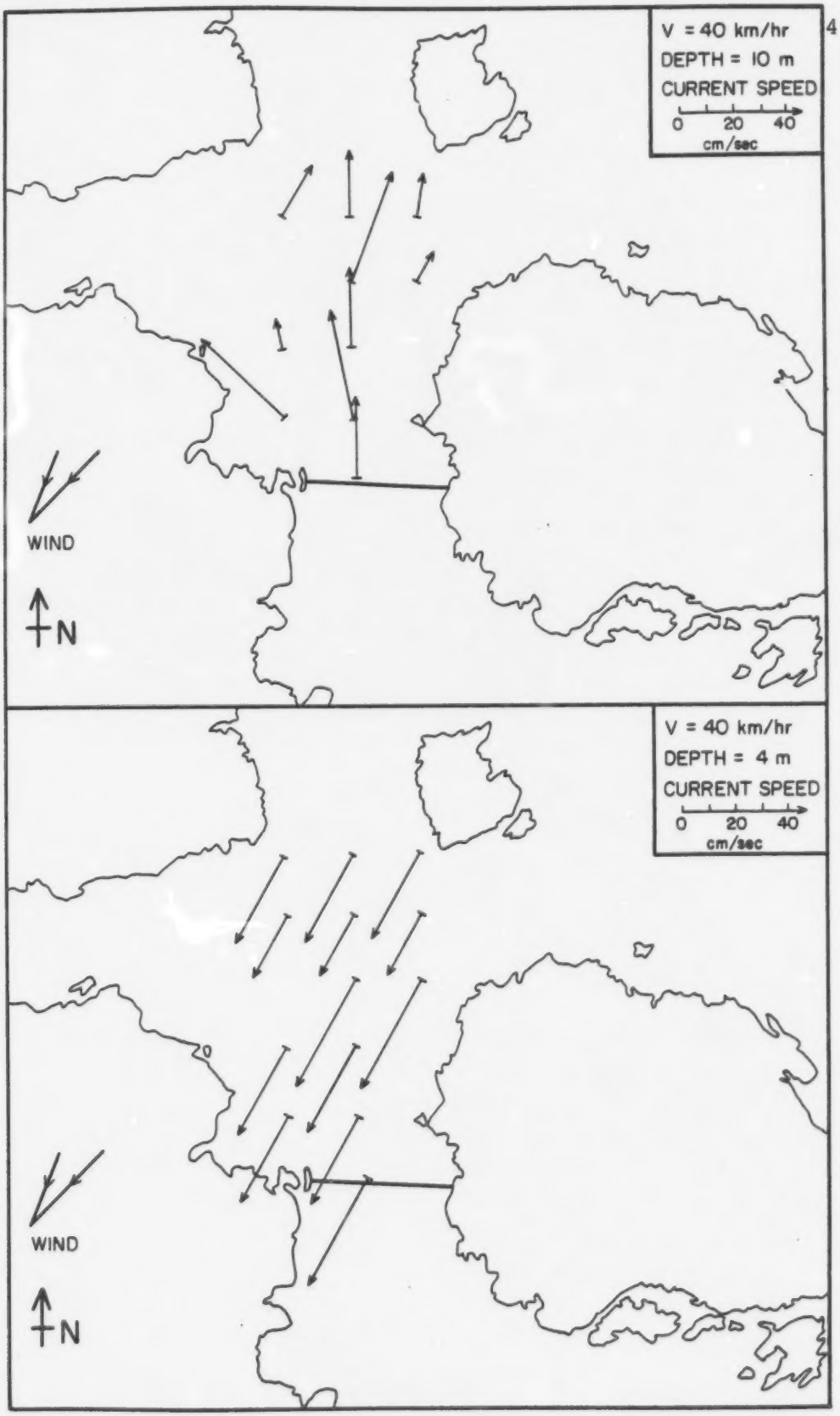


Figure 24 Currents on north side of causeway during winds from the north-northeast to northeast of 40 km/hr

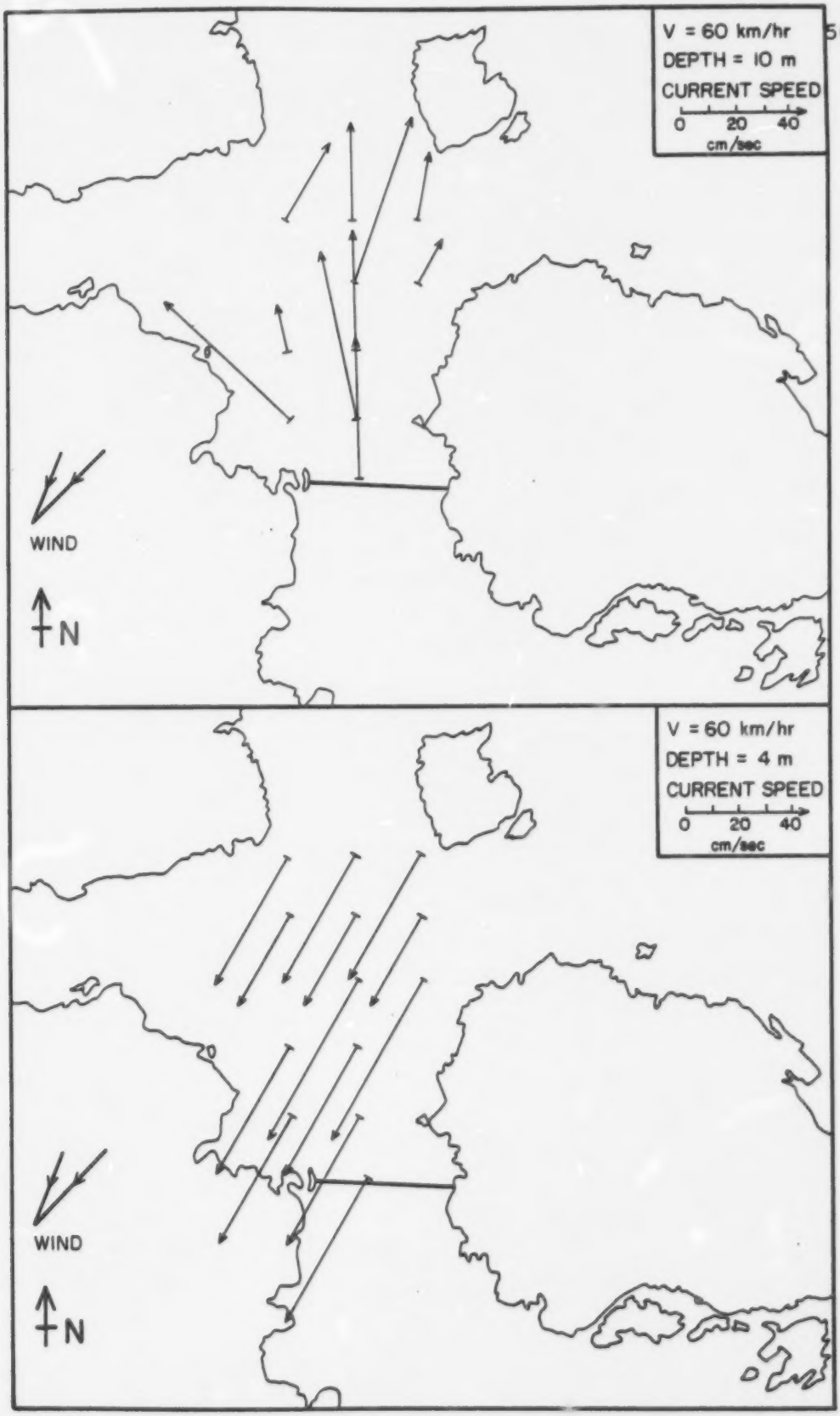


Figure 25 Currents on north side of causeway during winds from the north-northeast to northeast of 60 km/hr

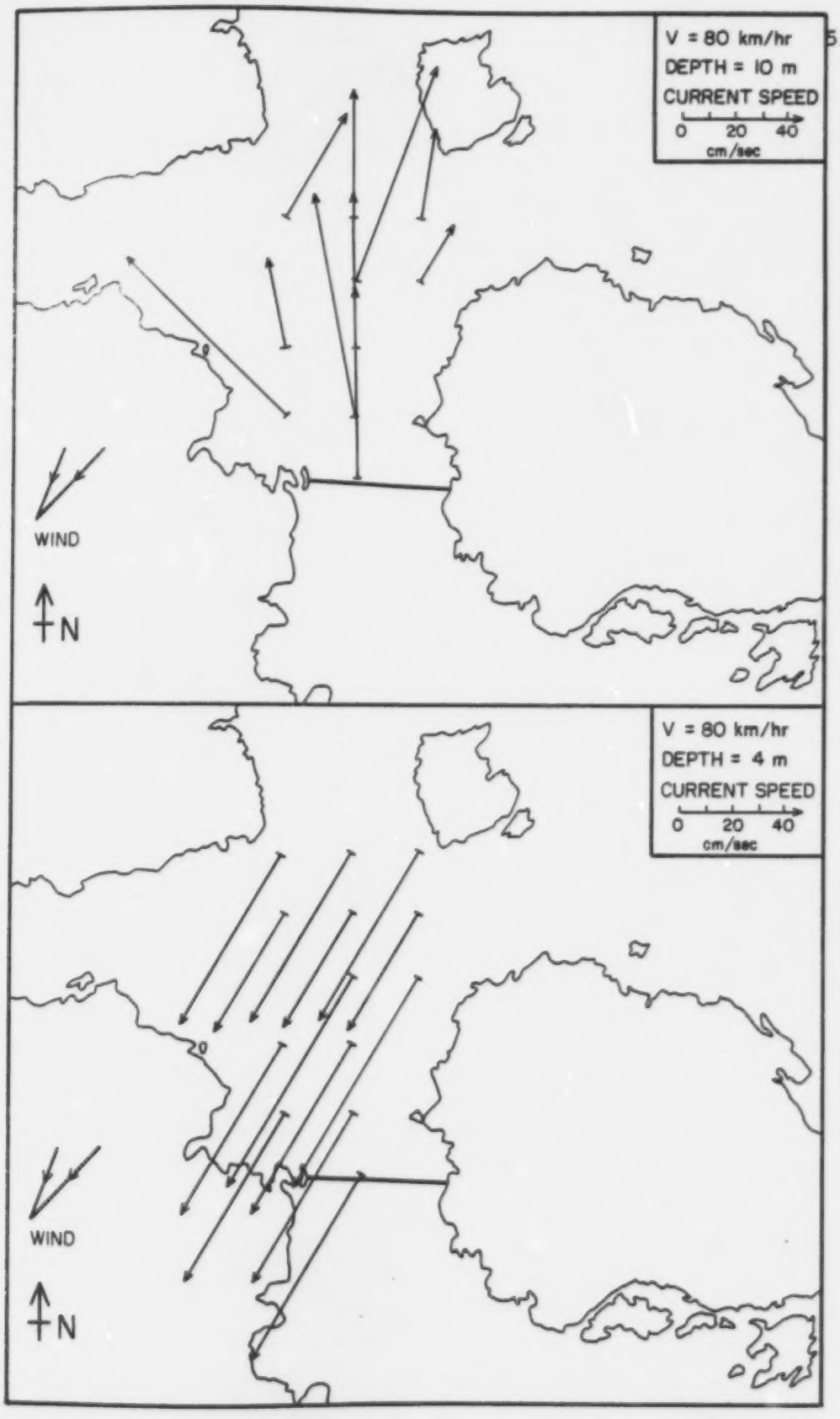


Figure 26 Currents on north side of causeway during winds from the north-northeast to northeast of 80 km/hr

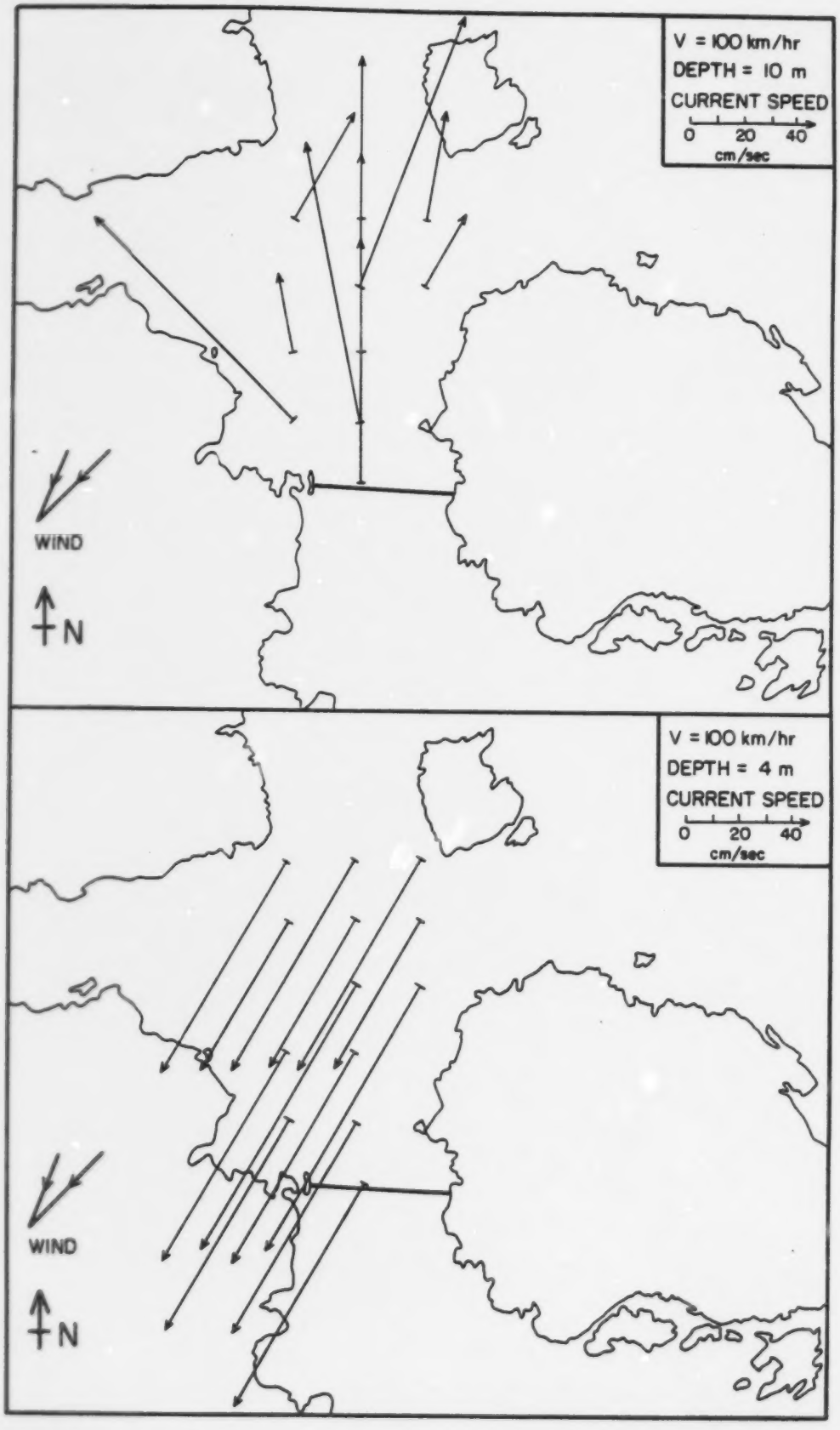


Figure 27 Currents on north side of causeway during winds from the north-northeast to northeast of 100 km/hr

Using this formula, the velocities in the bridge opening were found to vary from 25 cm/sec to 256 cm/sec when the winds were from the south to south-southeast with speeds between 10 and 100 km/hr. When the winds were from the north-northeast to northeast, the velocities in the opening varied from 30 cm/sec to 294 cm/sec.

The current velocities for each wind speed are given in Table 6. For a wind speed of 100 km/hr the maximum velocity will be approximately five knots. This value is an overestimate since the water level on the leeward side of the causeway will undergo some adjustment as the wind driven flow is producing the elevation in sea level on the windward side . Since the wind speeds are usually less than 60 km/hr, the velocities will tend to be less than three knots. This current velocity is not likely to cause any problems for the passage of small boats.

Greater velocities will occur if the tides are out of phase on one side of the causeway with respect to the other. The tidal level on the north side of the causeway is dependent on ebb and flood tide through the passages on both sides of Partridge Island. The passages are shallow and there is also an extensive shallow area northeast of Greenspond Island. Bottom friction in these shallow areas will play a larger role than in the area south of the causeway.

There is a high possibility that these frictional differences will cause the tidal levels to be out of phase. A tidal difference of 50 cm and a wind speed of 80 km/hr may produce a maximum current in the opening of approximately seven knots. The turbulence associated with such high currents may impede the maneuverability of small boats. This high current will not be persistent, but vary with tidal stage. For instance, if the high current occurs on flood tide the elevations of the combined effects of wind and tide will partially cancel each other on ebb tide such that the current will be less during ebb.

At the moment, there are no means of evaluating the extent to which the tides may be out of phase because the bathymetry of the study area is too complicated to make adequate estimates. The differences in tidal heights would have to be recorded by measuring the tidal heights on each side of the causeway after construction is completed. It is advisable that this exercise be carried out before the installation of the proposed bridge so that the potential problem can be properly evaluated.

## FISH AND FISHERIES

The construction of the causeway will have certain limited and temporary impacts on fish and fisheries. The deposit of unwashed rock fill will create some noise and sediment which could affect fish behaviour and movement in the area of infilling.

It is not known whether any leaching of material will occur when the rock fill is deposited.

Table 6. Current Velocities in the Bridge Opening.

| Wind Speed (km/hr) | South of Causeway<br>Current Velocity in the opening (cm/sec) | North of Causeway<br>Current Velocity in the opening (cm/sec) |
|---|---|---|
| 10 | 25 | 30 |
| 20 | 51 | 61 |
| 30 | 77 | 90 |
| 40 | 103 | 119 |
| 50 | 129 | 148 |
| 60 | 154 | 177 |
| 70 | 179 | 206 |
| 80 | 206 | 236 |
| 90 | 231 | 265 |
| 100 | 256 | 294 |

Fishing operations will be directly and indirectly affected by the construction phase. Traps, nets or other fishing gear will not be able to be set in the construction area. One salmon berth, one herring net berth and several lobster trap locations will be affected by construction activity.

The availability of construction jobs might reduce the numbers of active fishermen. This could affect fish landings and hence, fish plant work requirements. The extent of the phenomenon depends on the relative availability and attractiveness to fishermen of short term but possibly better paying jobs.

Operation

Longliners will no longer be able to pass through the Tickle as there is insufficient clearance available. This will cause some inconveniences and increase transit times. The Fishermens Committee in Badgers Quay-Valleyfield has, however formally supported the causeway, stating that the advantages to be gained by Greenspond residents more than offset this impact (A. Wicks pers. com.).

Upon completion of the causeway, an estimated 3.9 hectares of bottom habitat will be covered. This will be compensated by 3.0 hectares of slope on either side of the causeway. Until the substrate is settled by epibenthic life forms, this area will be a less suitable habitat.

The other impacts during operation will be discussed by species and a general consideration of effect on the fishery will follow.

Lobster

There are few studies of the impact of causeway construction on Lobster. The Canso Causeway was considered in a series of seminars (McCracken, 1979), however, the absence of pre-development information hampered any conclusive statements.

While one reseacher (Robinson, 1979) concluded that recruitment overfishing had caused failure of the lobster fishing in Chedabucto Bay, another (Dadswell, 1979) calculated that the causeway did reduce larval settlement in Chedabucto Bay and he postulated that this could have contributed to the failure of the lobster fishery in subsequent years. It appeared there was a net movement of larvae through Canso Straits from north to south.

In Greenspond Tickle there is no prevailing current flow so it is unlikely that the presence of the causeway will reduce larval settlement on either side of the causeway site. On the other hand, if the causeway causes the establishment of small gyres or calmer areas, this would encourage larval settlement and could favorably affect year class recruitment.

There have been several experiments where artificial substrates have been provided in an effort to increase lobster populations. The Greenspond causeway will provide somewhat less area of seabed habitat, but it may be physically more attractive to lobster, at least in providing temporary

refuges. Once the substrate is covered with an infauna it may also become attractive permanent habitat. As noted by G. Ennis (pers. com.), however, the limiting factor for lobster populations is clearly fishing mortality, ie there is probably unused habitat already available. Consequently it is unlikely that the availability of new habitat, per se, will increase lobster numbers.

If there is some increase in larval settlement near the causeway, it could be that some increase will occur in numbers reaching catchable size. This is highly speculative however, but may be worth monitoring.

The reduced inflow of cold water into the Tickle area can be expected to reduce the range of water temperature to which benthic fauna is exposed. For lobster such surges of cold water reduce mobility and hence, catchability. Given that catch rates are probably at a maximum now, there would not likely be any noticable inpact on the take of lobsters, however. The (average) area of such impact is limited - approximately 1.75 $km^2$ north of the causeway, and 2 $km^2$ south of it.

Salmon

Some salmon berths are located in the Tickle with most on the west (mainland) side. At least in years of abundance, salmon do pass through the Tickle. The predominant route however appears to pass along the east side of Greenspond Island and past the smaller islands to the southeast. As noted previously, prime salmon berths are located in this area.

Salmon whch try to enter the Tickle will either find their way though the bridge opening or will be diverted out around Greenspond Island. A short (5 km) diversion will have negligible impact on salmon energetics, but will affect catchability, since the longer the nearshore movement, the more nets a fish is likely to encounter.

It appears (Figure 11) that the general trend of salmon movement in the study area is southward, hence nets set along the north portion of Greenspond Island could intercept salmon being diverted from the Tickle. Nets immediately south of the causeway could be missed.

Should salmon find their way through the bridge opening there is likely to be minimum impact on fish or their catchability. The placement of the causeway could establish new berths if fish appear to pass the area.

In summary, it may be that some net berths (possibly those south of the causeway along the mainland) will have decreased catchability for salmon, whereas others will have an increase, the two tending to balance each other out.

Cod

Groundfish such as cod may be affected by altered temperature of bottom water. Cod tend to either stay below the intermediate cold water layer, or move to shore on the upper, warmer water. This latter inshore movement of young small cod appears to have been reduced in recent years and the trap fishery has declined. This may well be attributable to causes not related to temperature. The local change in bottom temperature could, however render the area of the Tickle more attractive habitat for cod, should they return inshore in any numbers. This impact will probably be subtle if detectable, and extend over a very limited area in any case.

Other Species

Herring and capelin may continue to pass through the Tickle using the bridge opening. There are anecdotal reports that such has been the case for herring at the Twillingate causeway.

Lumpfish would likely be unaffected by presence of the causeway.

## SUMMARY AND CONCLUSIONS

This report considers the changes in physical oceanographic conditions that will result from construction of a 0.8 km long rock fill causeway joining Greenspond Island, Bonavista Bay, Newfoundland to the mainland. The fishing impacts that will result from these oceanographic changes are postulated to provide imput to an Environmental Preview Report which is to be submitted by Department of Transportation to Department of Environment as an aid in deciding environmental requirements for this project.

A one month deployment of a current meter (mid-depth, mid-channel) showed that the physical oceanography of the study area is dominated by wind effects. There is minimal tidal element to water currents and the tide can run either direction through the Tickle, whether rising or falling. The occurrence of southerly (onshore) winds can draw colder, higher salinity Labrador Current water into the Tickle area. This results in dramatic changes in water temperature at the bottom, in the order of 3 Celsius degrees.

The local fishery is intensive, and based on longliners and open boats. It is the economic basis of the area, contributing $2.7 million (landed value) to the area in 1981. Two fish plants (one at Valleyfield and another at Greenspond) provide 400 seasonal jobs. Within the impact area the species of concern are primarily lobster and salmon.

The predicted changes that will occur relate mainly to the changed pattern of inflow of colder water with the occurrence of southerly winds. On the windward side of the causeway a set-up will occur whereby wind force will raise water elevation. This will create a water flow at depth in a direction opposite to the wind direction. Consequently, during southerly wind conditions there will no longer be an intrusion of this colder water, hence dramatic temperature changes will no longer occur. The area impacted by change in water current is relatively small - 1.75 $km^2$ north of the causeway; 2 $km^2$ to the south.

It is likely that tides north and south of the causeway location are out of phase. The presence of the causeway and a small bridge opening (1% of the present cross-sectional area of the Tickle), could create high current conditions on ebb and flood tide. These currents could be strong enough to hamper passage of small boats through the gap.

The impact on fishery is minimal. Some gear, mainly lobster pots will be dislocated. Longliners will not be able to use the Tickle but will have to pass outside Greenspond Island adding about five minutes steaming time.

The impact on lobster will relate mainly to changes in habitat. An area of 3.9 ha of existing substrate will be covered by the causeway and in its place will leave 3.0 ha of sloping rock fill. This may become attractive habitat for lobster once the area becomes populated with bottom dwelling life forms. It is unlikely that any impact will occur to affect settlement of larvae.

Salmon may be diverted around the causeway. If this occurs there may be a slight change in fishing success of some fishing locations, however it is unlikely that the total catch of the study area will be affected.

Cod may tend to come ashore more readily in the impact area, given the more moderate water temperature, however this would be an extremely subtle impact.

It is not considered likely that other species will be affected by the causeway.

A monitoring program is recommended to confirm tidal conditions in the area prior to installation of the bridge . In addition, it will be useful to confirm the predicted changes in water characteristics, and to monitor settlement in the newly created habitat area. This may prove useful in asessing other causeway projects in the province.

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# A P P E N D I X 1

## CURRENT PROFILES IN GREENSPOND TICKLE

McELHANNEY OFFSHORE SURVEYS
BRAYSTOKE PROFILING RECORD

JOB NUMBER: CLIENT:

STATION LOCATION: Station 1 (Near Mainland) 10 MAY 1982

OPERATORS:

TIME STATION STARTED G.M.T.: FINISHED G.M.T.:

| DEPTH OF INSTRUMENT | SPEED | DIRECTION | TIME |
|---|---|---|---|
| 2 m | .55 | 220 | 11:32 |
| 4 m | .59 | 210 | 11:34 |
| 6 m | .17 | 205 | 11:36 |
| 8 m | .19 | 240 | 11:38 |
| 10 m | .07 | 255 | 11:40 |
| 12 m | .08 | 230 | 11:42 |
| 14 m | .06 | 200 | 11:44 |
| 16 m | .10 | 170 | 11:45 |
| 18 m | .04 | 210 | 11:47 |
| | | | |
| Total Depth | | | |
| 9.5 fat. | | | |
| | | | |
| | | | |

OBSERVER:

McELHANNEY OFFSHORE SURVEYS
BRAYSTOKE PROFILING RECORD

18 JUNE 1982

JOB NUMBER: 087006 CLIENT: LeDrew

STATION LOCATION: West (Pond Tickle)

OPERATORS: Cyril McCormick & Tor Fosnaes

TIME STATION STARTED G.M.T. 13:35 FINISHED G.M.T. 13:49

| DEPTH OF INSTRUMENT IN METERS | SPEED IN KNOTS | DIRECTION MAGNETIC TOWARDS | TIME GMT |
|---|---|---|---|
| 2 | 0.59 | 165 | 13:36 |
| 4 | 0.51 | 195 | 13:38 |
| 6 | 0.44 | 195 | 13:39 |
| 8 | 0.44 | 230 | 13:41 |
| 10 | 0.41 | 220 | 13:43 |
| 12 | 0.44 | 210 | 13:44 |
| 14 | 0.41 | 225 | 13:46 |
| 16 | 0.46 | 175 | 13:47 |
| 18 | 0.46 | 220 | 13:48 |
| | | | |
| | | | |
| | | | |
| | | | |

OBSERVER:

McELHANNEY OFFSHORE SURVEYS
BRAYSTOKE PROFILING RECORD

JOB NUMBER: 087006 CLIENT: LeDrew 18 JUNE 1982

STATION LOCATION: Center (Pond Tickle)

OPERATORS: Cyril McCormick & Tor Fosnaes

TIME STATION STARTED G.M.T. 13:57 FINISHED G.M.T. 14:12

| DEPTH OF INSTRUMENT IN METERS | SPEED IN KNOTS | DIRECTION MAGNETIC TOWARDS | TIME GMT |
|---|---|---|---|
| 2 | 0.63 | 220 | 13:58 |
| 4 | 0.53 | 120 | 14:00 |
| 6 | 0.50 | 155 | 14:01 |
| 8 | 0.46 | 190 | 14:03 |
| 10 | 0.43 | 205 | 14:04 |
| 12 | 0.49 | 215 | 14:06 |
| 14 | 0.43 | 185 | 14:07 |
| 16 | 0.43 | 185 | 14:09 |
| 18 | 0.36 | 200 | 14:10 |
| 20 | 0.31 | 200 | 14:12 |
| | | | |
| | | | |
| | | | |

OBSERVER:

McELHANNEY OFFSHORE SURVEYS
BRAYSTOKE PROFILING RECORD

JOB NUMBER: 087006 CLIENT: LeDrew 18 JUNE 1982

STATION LOCATION: East (Pond Tickle)

OPERATORS: Cyril McCormick & Tor Fosnaes

TIME STATION STARTED G.M.T. 14:22 FINISHED G.M.T. 14:36

| DEPTH OF INSTRUMENT IN METERS | SPEED IN KNOTS | DIRECTION MAGNETIC TOWARDS | TIME GMT |
|---|---|---|---|
| 2 | 0.52 | 175 | 14:22 |
| 4 | 0.54 | 175 | 14:25 |
| 6 | 0.55 | 180 | 14:26 |
| 8 | 0.58 | 165 | 14:28 |
| 10 | 0.67 | 170 | 14:29 |
| 12 | 0.63 | 205 | 14:30 |
| 14 | 0.33 | 190 | 14:32 |
| 16 | 0.38 | 160 | 14:34 |
| 18 | 0.26 | 235 | 14:35 |
| | | | |
| | | | |
| | | | |
| | | | |

OBSERVER:

McELHANNEY OFFSHORE SURVEYS
BRAYSTOKE PROFILING RECORD

JOB NUMBER: 087006 CLIENT: LeDrew 18 JUNE 1982

STATION LOCATION: West Pond

OPERATORS: Cyril McCormick & Tor Fosnaes

TIME STATION STARTED G.M.T. 1800 FINISHED G.M.T. 1813

| DEPTH OF INSTRUMENT IN METERS | SPEED IN KNOTS | DIRECTION MAGNETIC TOWARDS | TIME GMT |
|---|---|---|---|
| 2 | 0.23 | 95 | 18:00 |
| 4 | 0.49 | 195 | 18:02 |
| 6 | 0.27 | 230 | 18:03 |
| 8 | 0.36 | 215 | 18:05 |
| 10 | 0.46 | 195 | 18:06 |
| 12 | 0.45 | 200 | 18:08 |
| 14 | 0.43 | 225 | 18:09 |
| 16 | 0.19 | 175 | 18:10 |
| 18 | 0.09 | 285 | 18:12 |
| | | | |
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OBSERVER:

McELHANNEY OFFSHORE SURVEYS
BRAYSTOKE PROFILING RECORD

JOB NUMBER: 087006 CLIENT: LeDrew 18 JUNE 1982

STATION LOCATION: Center (Pond Tickle)

OPERATORS: Cyril McCormick & Tor Fosnaes

TIME STATION STARTED G.M.T. 18:21 FINISHED G.M.T. 18:37

| DEPTH OF INSTRUMENT IN METERS | SPEED IN KNOTS | DIRECTION MAGNETIC TOWARDS | TIME GMT |
|---|---|---|---|
| 2 | 0.59 | 185 | 18:22 |
| 4 | 0.54 | 205 | 18:24 |
| 6 | 0.61 | 180 | 18:26 |
| 8 | 0.54 | 200 | 18:28 |
| 10 | 0.47 | 215 | 18:29 |
| 12 | 0.43 | 205 | 18:30 |
| 14 | 0.41 | 210 | 18:33 |
| 16 | 0.31 | 190 | 18:34 |
| 18 | 0.11 | 155 | 18:36 |
| | | | |
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OBSERVER:

McELHANNEY OFFSHORE SURVEYS
BRAYSTOKE PROFILING RECORD

JOB NUMBER: 087006 CLIENT: LeDrew 18 JUNE 1982

STATION LOCATION: East (Pond Tickle)

OPERATORS: Cyril McCormick & Tor Fosnaes

TIME STATION STARTED G.M.T. 18:44 FINISHED G.M.T. 18:56

| DEPTH OF INSTRUMENT IN METERS | SPEED IN KNOTS | DIRECTION MAGNETIC TOWARDS | TIME GMT |
|---|---|---|---|
| 2 | 0.64 | 175 | 18:45 |
| 4 | 0.51 | 215 | 18:47 |
| 6 | 0.51 | 200 | 18:48 |
| 8 | 0.45 | 185 | 18:50 |
| 10 | 0.36 | 255 | 18:52 |
| 12 | 0.35 | 220 | 18:54 |
| 14 | 0.32 | 230 | 18:55 |
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OBSERVER:

# A P P E N D I X 2

## WIND DATA FOR CAPE BONAVISTA

## FOR PERIOD 1971-1980

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN /82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA NFLD. / T.N. 8400600

# WIND SPEED VS DIRECTION
# VITESSE DU VENT EN FONCTION DE LA DIRECTION

FOR / POUR: JAN / JANV 1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN / MOYENNE | PERCENTAGE OF OCCURRENCES BY DIRECTION / PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | | | |
| NNE | 133 | 16 | 28 | 21 | 30 | 22 | 5 | 5 | 5 | 1 | | | 31.8 | 1.8 | 0.0 |
| NE | 126 | 8 | 11 | 23 | 35 | 15 | 12 | 14 | 4 | 2 | 2 | | 39.3 | 1.7 | 0.0 |
| ENE | 142 | 3 | 14 | 14 | 40 | 36 | 16 | 12 | 6 | 1 | | | 41.0 | 1.9 | 0.0 |
| E | 236 | 16 | 28 | 31 | 83 | 46 | 24 | 5 | 2 | | 1 | | 34.7 | 3.2 | 0.0 |
| ESE | 217 | 12 | 22 | 29 | 59 | 46 | 21 | 17 | 6 | 2 | 2 | 1 | 39.1 | 2.9 | 0.0 |
| SE | 244 | 14 | 31 | 49 | 73 | 34 | 31 | 7 | 4 | 1 | | | 34.9 | 3.3 | 0.0 |
| SSE | 284 | 19 | 50 | 54 | 69 | 43 | 33 | 10 | 5 | 1 | | | 33.9 | 3.8 | 0.0 |
| S | 466 | 26 | 156 | 136 | 90 | 37 | 18 | 1 | 2 | | | | 26.0 | 6.3 | 0.0 |
| SSW | 431 | 24 | 117 | 141 | 104 | 20 | 20 | 3 | 2 | | | | 27.1 | 5.8 | 0.0 |
| SW | 554 | 12 | 76 | 150 | 177 | 97 | 27 | 7 | 5 | 3 | | | 33.2 | 7.4 | 0.0 |
| WSW | 1,014 | 23 | 68 | 155 | 320 | 183 | 122 | 78 | 44 | 9 | 5 | 7 | 41.3 | 13.6 | 0.0 |
| W | 1,629 | 15 | 79 | 198 | 503 | 352 | 258 | 140 | 61 | 23 | | | 43.2 | 21.9 | 0.0 |
| WNW | 831 | 7 | 69 | 168 | 288 | 205 | 64 | 15 | 9 | 5 | 1 | | 37.1 | 11.2 | 0.0 |
| NW | 490 | 8 | 61 | 115 | 141 | 76 | 53 | 24 | 5 | 6 | 1 | | 36.3 | 6.6 | 0.0 |
| NNW | 330 | 9 | 40 | 82 | 107 | 51 | 25 | 9 | 7 | | | | 34.0 | 4.4 | 0.0 |
| N | 243 | 17 | 39 | 50 | 66 | 28 | 17 | 18 | 8 | | | | 34.3 | 3.3 | 0.0 |
| CALM/ CALME | 70 | | | | | | | | | | | | | 0.9 | |
| TOTAL | 7,440 | 229 | 689 | 1,416 | 2,185 | 1,291 | 746 | 365 | 175 | 54 | 12 | 8 | 36.04 | *100.0% | * 0.0% |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,440

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDERE LA REPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX A PARTIR DES DIZAINES DE DEGRES

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN 782
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRPIOS

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA
NFLD. / T.N.
8400600

## WIND SPEED VS DIRECTION
## VITESSE DU VENT EN FONCTION DE LA DIRECTION

FOR / POUR: FEB / FEV
1971-1980

WIND SPEED LIMIT
LIMITE DE VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN / MOYENNE | PERCENTAGE OF OCCURRENCES BY DIRECTION / PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | | | |
| NNE | 176 | 9 | 38 | 30 | 48 | 31 | 14 | 6 | | | | | 31.9 | 2.6 | 0.0 |
| NE | 189 | 10 | 30 | 21 | 40 | 50 | 25 | 13 | | | | | 36.8 | 2.8 | 0.0 |
| ENE | 178 | 8 | 23 | 31 | 50 | 27 | 21 | 18 | | | | | 36.5 | 2.6 | 0.0 |
| E | 188 | 14 | 34 | 46 | 42 | 21 | 22 | 5 | 4 | | | | 32.3 | 2.8 | 0.0 |
| ESE | 125 | 17 | 35 | 26 | 24 | 10 | 8 | 2 | 3 | | | | 27.6 | 1.8 | 0.0 |
| SE | 217 | 16 | 37 | 49 | 59 | 23 | 21 | 8 | 4 | | | | 32.8 | 3.2 | 0.0 |
| SSE | 264 | 24 | 69 | 66 | 69 | 18 | 10 | 7 | 1 | | | | 27.4 | 3.9 | 0.0 |
| S | 394 | 29 | 79 | 134 | 107 | 18 | 18 | 9 | | | | | 27.8 | 5.8 | 0.0 |
| SSW | 282 | 13 | 82 | 83 | 78 | 16 | 7 | 3 | | | | | 26.9 | 4.2 | 0.0 |
| SW | 498 | 13 | 92 | 194 | 133 | 34 | 30 | 5 | 3 | 4 | | | 30.2 | 7.3 | 0.0 |
| WSW | 930 | 33 | 60 | 212 | 278 | 152 | 122 | 38 | 27 | 7 | | 1 | 37.8 | 13.7 | 0.0 |
| W | 1,109 | 25 | 84 | 170 | 364 | 239 | 159 | 53 | 15 | | | | 36.8 | 16.3 | 0.0 |
| WNW | 760 | 18 | 45 | 112 | 297 | 160 | 78 | 29 | 12 | 7 | 1 | 1 | 38.7 | 11.2 | 0.0 |
| NW | 648 | 12 | 40 | 135 | 203 | 140 | 72 | 34 | 9 | 2 | 1 | | 38.4 | 9.5 | 0.0 |
| NNW | 483 | 10 | 50 | 93 | 139 | 95 | 64 | 23 | 4 | 5 | | | 37.6 | 7.1 | 0.0 |
| N | 266 | 18 | 71 | 45 | 51 | 53 | 20 | 7 | 1 | | | | 30.0 | 3.9 | 0.0 |
| CALM/ CALME | 85 | | | | | | | | | | | | | 1.3 | |
| TOTAL | 6,792 | 269 | 869 | 1,437 | 1,982 | 1,087 | 691 | 260 | 83 | 25 | 2 | 2 | 34.05 | *100.04 | * 0.04 |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 6,792

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDERE LA REPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX A PARTIR DES DIZAINES DE DEGRES

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN /82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

# WIND SPEED VS DIRECTION
# VITESSE DU VENT EN FONCTION DE LA DIRECTION

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA NFLD. / T.N. 8400600

FOR / POUR: MAR / MARS 1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN / MOYENNE | PERCENTAGE OF OCCURRENCES BY DIRECTION / POURCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | | | |
| NNE | 210 | 12 | 43 | 64 | 60 | 20 | 12 | 2 | | | | | 29.6 | 2.8 | 0.0 |
| NE | 328 | 19 | 48 | 69 | 83 | 41 | 41 | 21 | 5 | 1 | | | 35.3 | 4.4 | 0.0 |
| ENE | 227 | 29 | 31 | 44 | 55 | 43 | 21 | 3 | 1 | | | | 30.9 | 3.1 | 0.0 |
| E | 338 | 28 | 79 | 88 | 97 | 23 | 13 | 7 | 2 | 1 | | | 26.1 | 4.5 | 0.0 |
| ESE | 192 | 26 | 79 | 64 | 83 | 25 | 9 | 3 | 3 | | | | 27.4 | 3.9 | 0.0 |
| SE | 323 | 19 | 58 | 58 | 101 | 46 | 29 | 8 | 3 | 1 | | | 32.7 | 4.3 | 0.0 |
| SSE | 290 | 24 | 60 | 72 | 68 | 28 | 26 | 11 | 1 | | | | 30.2 | 3.9 | 0.0 |
| S | 524 | 33 | 111 | 163 | 119 | 56 | 36 | 4 | 2 | | | | 29.3 | 7.0 | 0.0 |
| SSW | 503 | 13 | 103 | 161 | 134 | 63 | 22 | 4 | 2 | 1 | | | 29.9 | 6.8 | 0.0 |
| SW | 794 | 23 | 98 | 238 | 276 | 84 | 47 | 20 | 4 | 4 | | | 32.7 | 10.7 | 0.0 |
| WSW | 830 | 29 | 90 | 196 | 267 | 97 | 80 | 49 | 17 | 5 | | | 35.9 | 11.2 | 0.0 |
| W | 879 | 42 | 109 | 185 | 230 | 139 | 94 | 51 | 22 | 6 | | 1 | 36.6 | 11.8 | 0.0 |
| WNW | 510 | 20 | 42 | 89 | 192 | 73 | 48 | 25 | 8 | 6 | 1 | 6 | 38.1 | 6.9 | 0.0 |
| NW | 488 | 21 | 47 | 58 | 158 | 101 | 64 | 25 | 3 | 6 | 4 | 1 | 39.0 | 6.6 | 0.0 |
| NNW | 388 | 21 | 60 | 99 | 127 | 44 | 18 | 12 | 2 | 3 | 1 | 1 | 32.5 | 5.2 | 0.0 |
| N | 388 | 22 | 88 | 115 | 109 | 36 | 10 | 5 | 1 | 2 | | | 28.4 | 5.2 | 0.0 |
| CALM/ CALME | 128 | | | | | | | | | | | | | 1.7 | |
| TOTAL | 7,440 | 381 | 1,143 | 1,763 | 2,159 | 919 | 570 | 250 | 76 | 36 | 6 | 9 | 32.54 | *100.04 | * 0.04 |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,440

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDÉRÉ LA RÉPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX À PARTIR DES DIZAINES DE DEGRÉS

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN /82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

# WIND SPEED VS DIRECTION
# VITESSE DU VENT EN FONCTION DE LA DIRECTION

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA
NFLD. / T.N.
8400600

FOR / POUR: APR / AVR
1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN / MOYENNE | PERCENTAGE OF OCCURRENCES BY DIRECTION / PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | | | |
| NNE | 153 | 29 | 59 | 43 | 14 | 6 | 1 | 1 | | | | | 20.4 | 2.1 | 0.0 |
| NE | 288 | 34 | 72 | 79 | 54 | 31 | 16 | | | | | | 26.2 | 4.0 | 0.0 |
| ENE | 294 | 47 | 110 | 60 | 51 | 16 | 8 | 2 | | | | | 22.4 | 4.1 | 0.0 |
| E | 581 | 55 | 192 | 149 | 123 | 38 | 14 | 10 | | | | | 25.1 | 8.1 | 0.0 |
| ESE | 636 | 39 | 217 | 197 | 143 | 24 | 14 | 2 | | | | | 24.5 | 8.4 | 0.0 |
| SE | 467 | 30 | 135 | 131 | 107 | 37 | 24 | 3 | | | | | 27.0 | 6.5 | 0.0 |
| SSE | 331 | 31 | 93 | 94 | 69 | 27 | 13 | 3 | 1 | | | | 26.4 | 4.6 | 0.0 |
| S | 449 | 30 | 122 | 140 | 118 | 26 | 12 | 1 | | | | | 26.2 | 6.2 | 0.0 |
| SSW | 335 | 19 | 74 | 132 | 101 | 8 | 1 | | | | | | 25.9 | 4.7 | 0.0 |
| SW | 639 | 30 | 127 | 236 | 199 | 28 | 18 | 1 | | | | | 27.6 | 8.9 | 0.0 |
| WSW | 528 | 49 | 134 | 149 | 151 | 42 | 3 | | | | | | 25.7 | 7.3 | 0.0 |
| W | 412 | 53 | 110 | 114 | 103 | 23 | 9 | | | | | | 24.5 | 5.7 | 0.0 |
| WNW | 438 | 51 | 70 | 71 | 161 | 54 | 29 | 2 | | | | | 30.0 | 6.9 | 0.0 |
| NW | 647 | 49 | 85 | 104 | 210 | 111 | 68 | 18 | 2 | | | | 33.9 | 9.0 | 0.0 |
| NNW | 538 | 27 | 86 | 126 | 122 | 75 | 76 | 25 | 1 | | | | 34.2 | 7.5 | 0.0 |
| N | 291 | 33 | 104 | 88 | 48 | 13 | 4 | 1 | | | | | 22.8 | 4.0 | 0.0 |
| CALM/ CALME | 173 | | | | | | | | | | | | | 2.4 | |
| TOTAL | 7,200 | 606 | 1,790 | 1,913 | 1,774 | 559 | 312 | 69 | 4 | | | | 26.47 | *100.0% | * 0.0% |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,200

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDERE LA REPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX A PARTIR DES DIZAINES DE DEGRES

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN /82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA NFLD. / T.N. 8400600

# WIND SPEED VS DIRECTION
## VITESSE DU VENT EN FUNCTION DE LA DIRECTION

FOR / POUR: MAY / MAI 1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN / MOYENNE | PERCENTAGE OF OCCURRENCES BY DIRECTION / PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | | | |
| NNE | 208 | 20 | 63 | 70 | 48 | 7 | | | | | | | 23.4 | 2.8 | 0.0 |
| NE | 319 | 50 | 89 | 75 | 71 | 21 | 7 | 2 | 1 | 3 | | | 25.0 | 4.3 | 0.0 |
| ENE | 295 | 50 | 84 | 49 | 58 | 30 | 21 | 3 | | | | | 25.9 | 4.0 | 0.0 |
| E | 528 | 88 | 176 | 114 | 102 | 43 | 4 | 1 | | | | | 22.5 | 7.1 | 0.0 |
| ESE | 588 | 68 | 213 | 198 | 98 | 5 | 6 | | | | | | 21.7 | 7.9 | 0.0 |
| SE | 472 | 29 | 156 | 177 | 94 | 9 | 7 | | | | | | 23.0 | 6.3 | 0.0 |
| SSE | 390 | 47 | 121 | 116 | 84 | 19 | 3 | | | | | | 23.3 | 5.2 | 0.0 |
| S | 449 | 40 | 135 | 162 | 91 | 19 | 2 | | | | | | 23.8 | 6.0 | 0.0 |
| SSW | 455 | 17 | 108 | 187 | 126 | 16 | 1 | | | | | | 25.7 | 6.1 | 0.0 |
| SW | 870 | 26 | 156 | 303 | 340 | 43 | 2 | | | | | | 27.9 | 11.7 | 0.0 |
| WSW | 574 | 46 | 151 | 145 | 173 | 46 | 8 | 2 | 1 | 1 | 1 | | 26.7 | 7.7 | 0.0 |
| W | 460 | 58 | 112 | 125 | 122 | 26 | 10 | 4 | 3 | | | | 25.7 | 6.2 | 0.0 |
| WNW | 338 | 31 | 73 | 85 | 124 | 18 | 5 | | 1 | 1 | | | 27.2 | 4.5 | 0.0 |
| NW | 402 | 31 | 66 | 95 | 139 | 34 | 22 | 10 | 3 | 2 | | | 30.8 | 5.4 | 0.0 |
| NNW | 454 | 39 | 71 | 114 | 145 | 66 | 16 | 1 | | | | | 29.6 | 6.1 | 0.0 |
| N | 450 | 38 | 129 | 140 | 92 | 30 | 14 | 2 | 5 | | | | 26.0 | 6.0 | 0.0 |
| CALM/ CALME | 188 | | | | | | | | | | | | | 2.5 | |
| TOTAL | 7,440 | 678 | 1,903 | 2,155 | 1,907 | 432 | 130 | 25 | 14 | 7 | 1 | | 24.98 | *100.0% | * 0.0% |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,440

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDERE LA REPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX A PARTIR DES DIZAINES DE DEGRES

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN 82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

# WIND SPEED VS DIRECTION
# VITESSE DU VENT EN FONCTION DE LA DIRECTION

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA NFLD. / T.N. 8400600

FOR / POUR: JUN / JUIN 1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN / MOYENNE | PERCENTAGE OF OCCURRENCES BY DIRECTION / PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | | | |
| NNE | 200 | 19 | 69 | 77 | 27 | 6 | 2 | | | | | | 22.3 | 2.8 | 0.0 |
| NE | 210 | 43 | 70 | 55 | 35 | 5 | 1 | 1 | | | | | 20.8 | 2.9 | 0.0 |
| ENE | 222 | 41 | 76 | 48 | 50 | 7 | | | | | | | 21.4 | 3.1 | 0.0 |
| E | 454 | 85 | 198 | 108 | 52 | 3 | 2 | 3 | 2 | 1 | | | 19.6 | 6.3 | 0.0 |
| ESE | 553 | 74 | 223 | 198 | 56 | 1 | 1 | | | | | | 20.0 | 7.7 | 0.0 |
| SE | 328 | 44 | 139 | 115 | 29 | 1 | | | | | | | 19.9 | 4.6 | 0.0 |
| SSE | 300 | 39 | 106 | 110 | 40 | 5 | | | | | | | 20.9 | 4.2 | 0.0 |
| S | 622 | 38 | 143 | 216 | 189 | 33 | 1 | 2 | | | | | 26.3 | 8.6 | 0.0 |
| SSW | 871 | 21 | 92 | 347 | 349 | 55 | 7 | | | | | | 29.3 | 12.1 | 0.0 |
| SW | 1,233 | 28 | 179 | 416 | 521 | 84 | 5 | | | | | | 29.3 | 17.1 | 0.0 |
| WSW | 488 | 51 | 146 | 125 | 132 | 26 | 8 | | | | | | 24.5 | 6.8 | 0.0 |
| W | 369 | 71 | 83 | 74 | 88 | 41 | 8 | 4 | | | | | 25.3 | 5.1 | 0.0 |
| WNW | 257 | 33 | 67 | 70 | 55 | 16 | 8 | 8 | | | | | 26.2 | 3.6 | 0.0 |
| NW | 283 | 30 | 60 | 71 | 73 | 25 | 19 | 5 | | | | | 28.3 | 3.9 | 0.0 |
| NNW | 319 | 32 | 65 | 92 | 92 | 10 | 7 | 10 | 6 | 5 | | | 28.9 | 4.4 | 0.0 |
| N | 307 | 32 | 93 | 129 | 46 | 3 | | 4 | | | | | 22.4 | 4.3 | 0.0 |
| CALM/ CALME | 184 | | | | | | | | | | | | | 2.6 | |
| TOTAL | 7,200 | 681 | 1,809 | 2,251 | 1,834 | 321 | 69 | 37 | 8 | 6 | | | 24.51 | *100.0% | * 0.0% |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,200

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDERE LA REPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX A PARTIR DES DIZAINES DE DEGRES

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN /82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA
NFLD. / T.N.
8400600

# WIND SPEED VS DIRECTION
## VITESSE DU VENT EN FONCTION DE LA DIRECTION

FOR / POUR: JLY / JUIL
1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | | MEAN | PERCENTAGE OF OCCURRENCES BY DIRECTION / PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | | MOYENNE | | |
| NNE | 96 | 24 | 33 | 26 | 13 | | | | | | | | 18.5 | 1.3 | 0.0 |
| NE | 123 | 31 | 39 | 36 | 17 | | | | | | | | 19.3 | 1.7 | 0.0 |
| ENE | 135 | 44 | 46 | 19 | 11 | 12 | 1 | 2 | | | | | 18.9 | 1.8 | 0.0 |
| E | 370 | 88 | 162 | 89 | 25 | 5 | 1 | | | | | | 17.8 | 5.0 | 0.0 |
| ESE | 662 | 74 | 274 | 218 | 81 | 14 | 1 | | | | | | 20.9 | 8.9 | 0.0 |
| SE | 431 | 37 | 176 | 137 | 75 | 5 | 1 | | | | | | 22.0 | 5.8 | 0.0 |
| SSE | 383 | 38 | 127 | 131 | 77 | 8 | 2 | | | | | | 22.9 | 5.1 | 0.0 |
| S | 663 | 39 | 152 | 276 | 174 | 14 | 8 | | | | | | 25.3 | 8.9 | 0.0 |
| SSW | 1,031 | 24 | 160 | 449 | 366 | 31 | 1 | | | | | | 27.5 | 13.9 | 0.0 |
| SW | 1,675 | 35 | 240 | 673 | 671 | 50 | 2 | 3 | 1 | | | | 28.4 | 22.5 | 0.0 |
| WSW | 687 | 72 | 213 | 204 | 168 | 23 | 6 | | 1 | | | | 23.8 | 9.2 | 0.0 |
| W | 280 | 59 | 93 | 63 | 46 | 12 | 5 | 2 | | | | | 21.5 | 3.8 | 0.0 |
| WNW | 188 | 37 | 43 | 42 | 36 | 23 | 7 | | | | | | 24.9 | 2.5 | 0.0 |
| NW | 173 | 23 | 56 | 37 | 42 | 14 | 1 | | | | | | 23.1 | 2.3 | 0.0 |
| NNW | 226 | 26 | 87 | 55 | 45 | 9 | 4 | | | | | | 22.7 | 3.0 | 0.0 |
| N | 156 | 24 | 63 | 38 | 31 | | | | | | | | 20.3 | 2.1 | 0.0 |
| CALM/ CALME | 161 | | | | | | | | | | | | | 2.2 | |
| TOTAL | 7,440 | 675 | 1,964 | 2,493 | 1,878 | 220 | 40 | 7 | 2 | | | | 23.85 | *100.0% | * 0.0% |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,440

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDERE LA REPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX A PARTIR DES DIZAINES DE DEGRES

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN /82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

# WIND SPEED VS DIRECTION
# VITESSE DU VENT EN FONCTION DE LA DIRECTION

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA NFLD. / T.N. 8400600

FOR / POUR: AUG / AOUT 1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN / MOYENNE | PERCENTAGE OF OCCURRENCES BY DIRECTION / PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | | | |
| NNE | 160 | 16 | 51 | 60 | 19 | 7 | | 3 | 4 | | | | 24.1 | 2.2 | 0.0 |
| NE | 259 | 35 | 84 | 87 | 45 | 5 | 1 | 2 | | | | | 21.9 | 3.5 | 0.0 |
| ENE | 188 | 34 | 50 | 67 | 29 | 7 | | 1 | | | | | 21.9 | 2.5 | 0.0 |
| E | 360 | 68 | 119 | 114 | 54 | 5 | | | | | | | 20.6 | 4.8 | 0.0 |
| ESE | 424 | 37 | 173 | 151 | 45 | 15 | 3 | | | | | | 21.6 | 5.7 | 0.0 |
| SE | 266 | 23 | 97 | 103 | 39 | 4 | | | | | | | 22.2 | 3.6 | 0.0 |
| SSE | 387 | 30 | 107 | 145 | 92 | 12 | | 1 | | | | | 24.5 | 5.2 | 0.0 |
| S | 647 | 25 | 190 | 260 | 152 | 16 | 3 | 1 | | | | | 24.8 | 8.7 | 0.0 |
| SSW | 730 | 15 | 100 | 338 | 260 | 15 | 1 | 1 | | | | | 27.9 | 9.8 | 0.0 |
| SW | 1,210 | 24 | 190 | 502 | 468 | 21 | 3 | 2 | | | | | 28.0 | 16.3 | 0.0 |
| WSW | 873 | 63 | 209 | 278 | 269 | 30 | 16 | 8 | | | | | 26.4 | 11.7 | 0.0 |
| W | 520 | 43 | 129 | 153 | 125 | 52 | 15 | 3 | | | | | 26.9 | 7.0 | 0.0 |
| WNW | 308 | 25 | 66 | 93 | 84 | 27 | 6 | 7 | | | | | 27.6 | 4.1 | 0.0 |
| NW | 345 | 24 | 71 | 99 | 110 | 33 | 3 | 3 | 2 | | | | 28.1 | 4.6 | 0.0 |
| NNW | 384 | 27 | 75 | 104 | 126 | 34 | 8 | 8 | 2 | | | | 26.8 | 5.2 | 0.0 |
| N | 254 | 28 | 94 | 86 | 32 | 6 | 4 | 3 | 1 | | | | 22.9 | 3.4 | 0.0 |
| CALM/ CALME | 125 | | | | | | | | | | | | | 1.7 | |
| TOTAL | 7,440 | 517 | 1,805 | 2,640 | 1,949 | 289 | 63 | 43 | 9 | | | | 25.27 | *100.0% | = 0.0% |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,440

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDERE LA REPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX A PARTIR DES DIZAINES DE DEGRES

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN /82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA NFLD. / T.N. 8400600

# WIND SPEED VS DIRECTION
# VITESSE DU VENT EN FUNCTION DE LA DIRECTION

FOR / POUR: SEP / SEPT 1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | MEAN | PERCENTAGE OF OCCURRENCES BY DIRECTION / PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 91- 90 | 91-100 101-999 | MOYENNE | | |
| NNE | 231 | 28 | 77 | 43 | 51 | 15 | 17 | | | | | 25.3 | 3.2 | 0.0 |
| NE | 206 | 32 | 60 | 39 | 46 | 21 | 8 | | | | | 24.6 | 2.9 | 0.0 |
| ENE | 143 | 28 | 50 | 35 | 18 | 7 | 4 | 1 | | | | 21.4 | 2.0 | 0.0 |
| E | 216 | 43 | 70 | 42 | 43 | 14 | 4 | | | | | 22.3 | 3.0 | 0.0 |
| ESE | 320 | 45 | 122 | 57 | 65 | 27 | 4 | | | | | 23.3 | 4.4 | 0.0 |
| SE | 300 | 16 | 88 | 75 | 101 | 16 | 4 | | | | | 26.5 | 4.2 | 0.0 |
| SSE | 322 | 20 | 91 | 106 | 85 | 14 | 6 | | | | | 25.4 | 4.5 | 0.0 |
| S | 717 | 40 | 184 | 263 | 183 | 38 | 8 | 1 | | | | 25.7 | 10.0 | 0.0 |
| SSW | 646 | 20 | 117 | 201 | 234 | 58 | 13 | 3 | | | | 29.2 | 9.0 | 0.0 |
| SW | 845 | 20 | 147 | 296 | 332 | 42 | 8 | | | | | 28.4 | 11.7 | 0.0 |
| WSW | 817 | 41 | 155 | 264 | 230 | 82 | 38 | 7 | | | | 29.2 | 11.3 | 0.0 |
| W | 796 | 40 | 102 | 189 | 239 | 137 | 66 | 19 | 4 | | | 33.4 | 11.1 | 0.0 |
| WNW | 414 | 12 | 57 | 91 | 135 | 70 | 34 | 14 | 1 | | | 33.9 | 5.8 | 0.0 |
| NW | 333 | 25 | 52 | 74 | 94 | 42 | 26 | 15 | 5 | | | 32.6 | 4.6 | 0.0 |
| NNW | 418 | 19 | 63 | 96 | 133 | 58 | 27 | 11 | 10 | 1 | | 33.2 | 5.9 | 0.0 |
| N | 386 | 30 | 100 | 117 | 90 | 34 | 12 | 3 | | | | 26.5 | 5.4 | 0.0 |
| CALM/ CALME | 90 | | | | | | | | | | | | 1.3 | |
| TOTAL | 7,200 | 459 | 1,535 | 1,988 | 2,079 | 675 | 279 | 74 | 20 | 1 | | 28.21 | *100.0% | * 0.0% |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,203

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDERE LA REPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX A PARTIR DES DIZAINES DE DEGRES

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN 82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA NFLD. / T.N. 8400600

# WIND SPEED VS DIRECTION
# VITESSE DU VENT EN FONCTION DE LA DIRECTION

FOR / POUR: OCT / OCT 1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

PERCENTAGE OF OCCURRENCES BY SPEEDS & DIRECTION

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN | PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 90 | 81- 90 | 91-100 | 101-999 | MOYENNE | | |
| NNE | 97 | 14 | 22 | 18 | 13 | 18 | 6 | 4 | 2 | | | | 29.7 | 1.3 | 0.0 |
| NE | 111 | 10 | 41 | 29 | 14 | 14 | 3 | | | | | | 24.9 | 1.5 | 0.0 |
| ENE | 160 | 15 | 28 | 48 | 46 | 17 | 4 | 2 | | | | | 28.3 | 2.2 | 0.0 |
| E | 266 | 27 | 54 | 64 | 65 | 37 | 14 | 1 | 2 | 2 | | | 29.3 | 3.6 | 0.0 |
| ESE | 248 | 15 | 63 | 57 | 74 | 20 | 12 | 6 | 1 | | | | 28.9 | 3.3 | 0.0 |
| SE | 326 | 19 | 67 | 56 | 115 | 49 | 14 | 6 | | | | | 30.6 | 4.4 | 0.0 |
| SSE | 390 | 24 | 83 | 106 | 124 | 36 | 13 | 1 | 3 | | | | 28.6 | 5.2 | 0.0 |
| S | 566 | 20 | 138 | 232 | 147 | 24 | 5 | | | | | | 26.1 | 7.6 | 0.0 |
| SSW | 519 | 18 | 98 | 219 | 147 | 25 | 9 | 2 | 1 | | | | 27.5 | 7.0 | 0.0 |
| SW | 710 | 24 | 107 | 227 | 264 | 59 | 16 | 10 | 2 | | | 1 | 30.1 | 9.5 | 0.0 |
| WSW | 958 | 26 | 106 | 229 | 372 | 129 | 60 | 27 | 7 | 2 | | | 34.1 | 12.9 | 0.0 |
| W | 1,009 | 28 | 85 | 197 | 370 | 195 | 93 | 34 | 6 | 1 | | | 36.1 | 13.6 | 0.0 |
| WNW | 547 | 17 | 62 | 103 | 220 | 68 | 43 | 18 | 13 | 3 | | | 35.5 | 7.4 | 0.0 |
| NW | 566 | 9 | 49 | 107 | 213 | 79 | 68 | 28 | 10 | 3 | | | 37.8 | 7.6 | 0.0 |
| NNW | 561 | 13 | 57 | 98 | 138 | 99 | 92 | 44 | 18 | 2 | | | 39.9 | 7.5 | 0.0 |
| N | 347 | 16 | 55 | 94 | 99 | 62 | 11 | 5 | 4 | 1 | | | 31.7 | 4.7 | 0.0 |
| CALM/ CALME | 59 | | | | | | | | | | | | | 1.8 | |
| TOTAL | 7,440 | 295 | 1,115 | 1,884 | 2,421 | 931 | 463 | 188 | 69 | 14 | | 1 | 32.26 | *100.0% | * 0.0% |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,440

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDÉRÉ LA RÉPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX À PARTIR DES DIZAINES DE DEGRÉS

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN /82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

PROJECT NUKSER
NUMERO DU PROJET: 02626

STATION: BONAVISTA NFLD. / T.No 8400600

# WIND SPEED VS DIRECTION
## VITESSE DU VENT EN FONCTION DE LA DIRECTION

FOR / POUR: NOV / NOV 1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN | PERCENTAGE OF OCCURRENCES BY DIRECTION / POURCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | MOYENNE | | |
| NNE | 196 | 14 | 23 | 42 | 62 | 31 | 19 | 3 | 1 | 1 | | | 33.7 | 2.7 | 0.0 |
| NE | 205 | 17 | 35 | 43 | 55 | 18 | 21 | 12 | 2 | | 1 | 1 | 35.2 | 2.8 | 0.0 |
| ENE | 193 | 13 | 40 | 39 | 54 | 27 | 11 | 4 | | 3 | 2 | | 32.3 | 2.7 | 0.0 |
| E | 284 | 16 | 51 | 51 | 71 | 42 | 27 | 17 | 3 | 5 | 1 | | 35.2 | 3.9 | 0.0 |
| ESE | 264 | 15 | 40 | 57 | 72 | 48 | 24 | 8 | | | | | 33.3 | 3.7 | 0.0 |
| SE | 311 | 13 | 56 | 76 | 114 | 28 | 16 | 6 | 2 | | | | 31.3 | 4.3 | 0.0 |
| SSE | 338 | 13 | 53 | 79 | 129 | 28 | 27 | 9 | | | | | 32.2 | 4.7 | 0.0 |
| S | 503 | 14 | 147 | 168 | 120 | 32 | 15 | 3 | 1 | 1 | | 2 | 27.3 | 7.0 | 0.0 |
| SSW | 447 | 15 | 88 | 144 | 122 | 53 | 16 | 8 | | | | 1 | 30.0 | 6.2 | 0.0 |
| SW | 641 | 12 | 80 | 174 | 265 | 71 | 24 | 10 | 4 | | 1 | | 32.6 | 8.9 | 0.0 |
| WSW | 882 | 18 | 68 | 170 | 342 | 153 | 62 | 41 | 20 | 7 | 1 | | 37.5 | 12.3 | 0.0 |
| W | 1,065 | 27 | 91 | 165 | 345 | 246 | 125 | 41 | 21 | 4 | | | 36.3 | 14.8 | 0.0 |
| WNW | 598 | 12 | 39 | 102 | 196 | 145 | 71 | 33 | | | | | 38.2 | 8.3 | 0.0 |
| NW | 489 | 7 | 31 | 88 | 176 | 107 | 62 | 13 | 4 | 1 | | | 37.7 | 6.8 | 0.0 |
| NNW | 415 | 10 | 22 | 85 | 123 | 73 | 47 | 29 | 24 | 2 | | | 40.4 | 5.9 | 0.0 |
| N | 325 | 11 | 40 | 101 | 104 | 28 | 16 | 9 | 7 | 7 | 2 | | 34.3 | 4.5 | 0.0 |
| CALM/ CALME | 44 | | | | | | | | | | | | | 0.6 | |
| TOTAL | 7,200 | 227 | 904 | 1,584 | 2,350 | 1,130 | 583 | 246 | 89 | 31 | 8 | 4 | 34.74 | *100.04 | * 0.04 |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,200

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDERE LA REPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX A PARTIR DES DIZAINES DE DEGRES

DATE OF RUN / DATE DU PASSAGE : 30 JUN / JUIN /82
TIME OF RUN / HEURE DU PASSAGE: 1444
PROGRAM / PROGRAMME : GRP105

# W I N D  S P E E D  V S  D I R E C T I O N
## VITESSE DU VENT EN FONCTION DE LA DIRECTION

PROJECT NUMBER
NUMERO DU PROJET: 02626

STATION: BONAVISTA NFLD. / T.N. 8400600

FOR / POUR: DEC / DEC 1971-1980

WIND SPEED LIMIT
LIMITE LA VITESSE: 999

| WIND DIRECTION / DIRECTION DU VENT | | WIND SPEED CLASSES / CLASSES DES VITESSES DE VENT (KM/H) | | | | | | | | | | | MEAN / MOYENNE | PERCENTAGE OF OCCURRENCES BY DIRECTION / PERCENTAGE DES OCCURRENCES SELON LA DIRECTION | % OF SPEEDS > LIMIT / % DES VITESSES > LIMITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1- 10 | 11- 20 | 21- 30 | 31- 40 | 41- 50 | 51- 60 | 61- 70 | 71- 80 | 81- 90 | 91-100 | 101-999 | | | |
| NNE | 187 | 14 | 26 | 51 | 64 | 10 | 8 | 8 | | | | | 30.6 | 2.5 | 0.0 |
| NE | 162 | 8 | 47 | 36 | 47 | 12 | 5 | 6 | 1 | | | | 28.3 | 2.2 | 0.0 |
| ENE | 159 | 13 | 18 | 25 | 37 | 21 | 23 | 19 | 3 | | | | 37.4 | 2.1 | 0.0 |
| E | 274 | 18 | 37 | 62 | 74 | 34 | 32 | 8 | 5 | 4 | | | 34.6 | 3.7 | 0.0 |
| ESE | 242 | 11 | 31 | 30 | 69 | 20 | 42 | 26 | 8 | 2 | 2 | 1 | 40.7 | 3.3 | 0.0 |
| SE | 265 | 15 | 28 | 52 | 79 | 36 | 28 | 17 | 7 | 3 | | | 37.0 | 3.0 | 0.0 |
| SSE | 418 | 19 | 55 | 81 | 110 | 62 | 48 | 24 | 11 | 6 | 2 | | 36.9 | 5.6 | 0.0 |
| S | 526 | 25 | 136 | 139 | 145 | 51 | 19 | 9 | 1 | 1 | | | 28.7 | 7.1 | 0.0 |
| SSW | 346 | 19 | 89 | 107 | 94 | 26 | 9 | 2 | | | | | 27.0 | 4.7 | 0.0 |
| SW | 432 | 13 | 65 | 122 | 134 | 63 | 25 | 8 | 2 | | | | 31.9 | 5.8 | 0.0 |
| WSW | 762 | 10 | 78 | 132 | 223 | 120 | 94 | 42 | 34 | 19 | 6 | 4 | 40.7 | 10.2 | 0.0 |
| W | 1,506 | 20 | 92 | 202 | 370 | 323 | 231 | 155 | 72 | 33 | 8 | | 43.9 | 20.2 | 0.0 |
| WNW | 796 | 13 | 47 | 140 | 325 | 141 | 85 | 25 | 13 | 3 | 2 | 2 | 37.9 | 10.7 | 0.0 |
| NW | 456 | 7 | 57 | 73 | 152 | 97 | 53 | 13 | 3 | 1 | | | 36.6 | 6.1 | 0.0 |
| NNW | 402 | 17 | 54 | 61 | 101 | 71 | 71 | 24 | 3 | | | | 37.6 | 5.4 | 0.0 |
| N | 426 | 17 | 49 | 106 | 138 | 56 | 42 | 17 | 1 | | | | 34.2 | 5.7 | 0.0 |
| CALM/ CALME | 81 | | | | | | | | | | | | | 1.1 | |
| TOTAL | 7,440 | 239 | 909 | 1,419 | 2,162 | 1,149 | 815 | 403 | 164 | 72 | 20 | 7 | 36.65 | *100.0% | * 0.04 |

* TOTAL NUMBER OF OCCURRENCES BEFORE SELECTION / NOMBRE TOTAL D OCCURRENCES AVANT SELECTION: 7,460

16 POINT DISTRIBUTION FROM 10'S OF DEGREES IS WEIGHTED IN THE 4 CARDINAL POINTS
ON A PONDÉRÉ LA RÉPARTITION EN 16 POINTS AUX 4 POINTS CARDINAUX À PARTIR DES DIZAINES DE DEGRÉS